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16. Abstracts

This report describes a study of certain applications of the Implementation Planning Program (IPP), undertaken as a part of Phase III of the Regional Air Pollution Analysis Project. The Implementation Planning Program is an air resource management planning tool which includes mathematical models representing the atmospheric diffusion of pollutants, the cost and effectiveness of pollution control measures, and the potential air quality impact of air pollution control strategies upon which control legislation may be based. The following objectives are examined here: 1. Estimation of the demand for control measures generated by the need to meet the requirements of the Clean Air Act, as amended; 2. Examination of the emission standards which were used in the Cost of Clean Air Report of the Clean Air Act, and to determine if the assumption that these emission standards will achieve air quality standards is valid; 3. Observation of the operational data requirements of an IPP type analysis, to determine whether or not these requirements may be relaxed and the corresponding data collection problems reduced.

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1.0 EXECUTIVE SUMMARY

This section is intended to provide an overview of the study objectives and a summary of the conclusions and recommendations. Technical backup data and detailed descriptions of the study procedures are presented in Sections 2.0 through 5.0.

1.1 THE IMPLEMENTATION PLANNING PROGRAM

This report describes a study of certain applications of the Implementation Planning Program (IPP), undertaken as a part of Phase III of the Regional Air Pollution Analysis Project. The Implementation Planning Program is an air resource management planning tool which has been developed by TRW over a period of two years under contract to the Air Pollution Control Office (APCO). IPP includes mathematical models representing the atmospheric diffusion of pollutants, the cost and effectiveness of pollution control measures, and the potential air quality impact of air pollution control strategies upon which control legislation may be based. IPP thus provides an objective means for analyzing both the extent of a region's air pollution problem and the adequacy of potential solutions.

IPP is currently being used in the preparation of implementation plans by a number of States and has been used by TRW in the preparation of Implementation Plans for Cincinnati and Washington, D.C. In this report some other applications of IPP will be evaluated.

1.2 STUDY OBJECTIVES

Now that the Implementation Planning Program is completed, it is of interest to look at several questions relating to the operational use of the program. The primary question to be answered by this study is whether or not a regionally oriented program such as IPP can be used to answer national-level questions in the air pollution control area. A second question to be answered has to do with the validity of the assumption made in the Cost of Clean Air Report (submitted by APCO to the Congress) relating emission standards to air quality standards. The diffusion model segment of IPP makes it possible to determine whether or not this assumption is valid, i.e., do the emission standards achieve the air quality standards. The third question concerns the input data requirements for IPP in an operational environment, i.e., whether or not existing emission inventory data (collected using a modified Rapid Survey technique; see Reference 3) is adequate to run the program.

There are a number of national level questions which might be asked regarding the air pollution control problem. The one selected for analysis here is that of estimating the demand for control measures generated by the need to meet the requirements of the Clean Air Act, as amended. Of particular concern is the demand for low sulfur fuels and the relative trade-off between fuel use and flue-gas desulfurization devices. Since the Nation's fossil fuel sources are not unlimited, an estimate of the national demand for fossil fuels, both in terms of magnitude and mix (fuel types and grades) is of great importance. Most of the resources of the study will be devoted to trying to answer this question using IPP.

The second objective is to look at the emission standards which were used in the Cost of Clean Air Report (Section 305(a) of the Clean Air Act, as amended) and to determine whether or not the assumption that these emission standards will achieve air quality standards is valid. Since the 305(a) report is designed to present a comprehensive study of the economic impact of the Act, it is essential that the estimated costs reflect what is actually required to achieve air quality standards. Because of the tremendous number of regions included in the 305(a) report, it is not feasible to do an air diffusion modeling study for every region; consequently, some uniform emission standards must be assumed for application throughout the United States. The approach here will be to look at the air quality impact of these assumed emission standards in selected regions where there is sufficient data to do a detailed diffusion modeling study.

The final objective is to look at the operational data requirements of an IPP type analysis, to determine whether or not these requirements may be relaxed and the corresponding data collection problems reduced.

1.3 STUDY ASSUMPTIONS

Detailed emission inventories for Cincinnati, St. Louis and Washington, D.C. will be used in several portions of the study; for

Cincinnati and Washington, these are the same inventories used in preparing Implementation Plans. When evaluating the Rapid Survey data (available only for Cincinnati and St. Louis), the detailed inventories will be assumed to be correct.

To allow comparison between the three control measure estimation techniques, the same emission standards will be used in all three approaches. The implicit assumption is made that these emission standards are adequate to achieve air quality in each of the regions under study. The specific emission standards used are presented in Table 1-1. All control cost outputs will be compared in terms of annualized costs (operations and maintenance plus annualized capital costs) in 1967-68 dollars. Instantaneous compliance with the Clean Air Act is assumed, i.e., there is no finite time period allocated for achieving compliance with the Act. The control costs computed will be those for controlling particulates and sulfur dioxides as emitted by point sources. The 305(a) background data will be that to be used in the 1971 Economics of Clean Air report.

1.4 ESTIMATING NATIONAL LEVEL CONTROL MEASURE DEMAND

The primary question to be answered is whether or not the IPP can be used to estimate the national level demand for control measure of all types, especially fuel substitution. The estimation procedure involves simply running as many regions as possible through IPP and adding up the total demand generated by complying with the emission standards in each region. Theoretically this approach is valid; the question is whether or not the quality of the data which is available at the present time for a large number of regions is adequate for use in the IPP. Because this technique is basically a summation over regional results, it has been labeled the Aggregation Approach.

Two other procedures which have been suggested for estimating national level control measure demand were also evaluated; each of them requires considerably less work than the Aggregation Approach described above. One of these techniques, which has been labeled the Extrapolation Approach, involves the intensive study of three regions and an evaluation of the validity of extrapolating these intensive results to national level. The

PARTICULATES

FC: MARYLAND COMBUSTION REGULATION

IP: SAN FRANCISCO PROCESS WEIGHT CURVE

SW: NEW YORK STATE INCINERATOR CURVE

SO_X

FC: 1.46 LBS / 10^6 (EQUIVALENT TO 1% SULFUR COAL)

IP: EXHAUST GAS CONCENTRATION LIMIT, 500 PPM

Note: These emission standards are defined in detail in Appendix D.

TABLE 1-1. EMISSION STANDARDS USED IN COMPARISON

other technique, labeled the 305(a) Approach (the third of three candidates considered in this study), relies on the use of existing 305(a) background cost data and looks at the possibility of tabulating the control measure demand implied by these cost data.

In order to limit the number of source categories which must be considered in the initial comparison of the three demand estimation approaches, it is of interest to look at the three regions to be used in this study to see if the intuitive feeling that powerplant emissions dominate the total regional emission picture is, in fact, correct. In Table 1-2, the steam electric powerplant contribution to each of the three regions is presented in terms of particulate and SO_2 emissions in tons per day. In the left-hand column, the source category breakdown is presented with the two major fuel combustion source types included, i.e., powerplants and industrial boilers. The numbers in parentheses indicate the relative contribution of these particular fuel combustion sources to the total fuel combustion emissions in the region. This table shows that the powerplant contribution varies from a low of 42% of the particulate emissions in St. Louis to a high of 58% of the particulate emissions in Cincinnati. The powerplant contribution to sulfur dioxide emissions is even greater, varying from a low of 63% in St. Louis to a high of 91% in Washington. The total contribution of fuel combustion sources to the regional emissions, (as indicated in the last line of the table) never falls below 70% and reaches a high of 100% for sulfur dioxide emissions in Washington. Clearly, fuel combustion sources (especially powerplants) are the dominant sources of emissions of these two pollutants and should be the first source category considered in evaluating the three candidate approaches to control measure demand estimation.

1.4.1 Aggregation Approach

There is no doubt that this approach is theoretically correct, i.e., if enough regions are run through IPP with adequate input data, summing over the regional results will give a good estimate of national control measure demand (assuming an iteration or two to allow fuel prices to adjust to increased demand). Thus, the question is whether or not the emission inventory data now available is adequate to produce meaningful national estimates of control measure demand. These lower-level-detail

	REGIONAL EMISSIONS, TONS/DAY					
	CINCINNATI		ST. LOUIS		WASHINGTON	
	PART.	SO_2	PART.	SO_2	PART.	SO_2
FUEL COMBUSTION	296	962	309	1307	62	542
POWERPLANTS	(224)	(876)	(188)	(1030)	(36)	(492)
INDUSTRIAL BOILERS	(70)	(82)	(116)	(263)	(-)	(3)
INDUSTRIAL PROCESS	68	24	130	325	10	-
SOLID WASTE	22	0	7	0	14	-
	387	986	447	1632	86	542
POWERPLANT CONTRIBUTION TO EXISTING EMISSIONS	58%	89%	42%	63%	43%	91%
FUEL COMBUSTION TO EXISTING EMISSIONS	77%	98%	69%	80%	72%	100%

TABLE 1-2. IMPACT OF STEAM ELECTRIC POWERPLANTS

or Rapid Survey emission inventories have been collected for some 40 regions, and the data is currently on file in APCO's Division of Air Quality and Emission data. The first task in evaluating this Aggregation Approach is to examine these Rapid Survey emission inventories to determine if they would be adequate. Two of the regions for which detailed inventories are available are also covered by the Rapid Survey inventories: Cincinnati and St. Louis. The Rapid Survey inventory differs from the detailed inventory in the number of point sources (10 to 50 per region rather than several hundred) and the amount of time expended in compiling the inventory. The detailed inventory requires on the order of one man year or more to assemble, while the Rapid Survey inventory can be completed in three to six weeks. The data which exists in AQED files, and which is to be the subject of this study, was not collected using the complete Rapid Survey technique as described in the publication by Ozolins and Smith. It was collected using somewhat less manpower (1 to 2 weeks rather than 3 to 6 weeks), and was intended primarily to serve as the data base for air quality control region designation work.

On completion of the IPP runs using the Rapid Survey data, the results were compared with those obtained using the detailed inventory from the following standpoints:

- Accuracy of emission inventory
- Air quality prediction
- Control device demand prediction
- Resources required per region for analysis

In comparing the Rapid Survey and detailed emission inventories, it is important to keep in mind that less detail is expected, i.e., there will be fewer point sources and, generally, the major point sources won't be reported on a stack-by-stack basis. However, to be sure that the same region is being described, some characteristics must agree with those in the detailed inventory, i.e., the overall (or "net") descriptions of the large major sources and the total regional emissions must agree.

In Table 1-3, a comparison of the Rapid Survey and detailed emission inventories is presented for Cincinnati and St. Louis on a regionwide basis. As can be seen by examining the column in the center of the table marked "Total," the variation, with one exception, is not too great; in

	REGIONAL EMISSIONS (TONS/DAY)						NUMBER OF SOURCES			
	POINT	AREA	FC	IP	SW	TOTAL	FC	IP	SW	TOTAL
CINCINNATI										
PARTICULATES										
DETAILED INVENTORY	386.7	212.6	296.0	68.3	22.4	599.3	71	34	20	125
RAPID SURVEY	211.1	158.8	199.2	5.4	6.4	369.9	44	8	6	58
SO_2										
DETAILED INVENTORY	986.1	369.4	962.5	23.5	0	1,355.5	71	6	0	77
RAPID SURVEY	1,054.7	104.3	1,052.3	2.4	0	1,159.0	43	1	0	44
ST. LOUIS										
PARTICULATES										
DETAILED INVENTORY	446.8	108.3	309.5	130.3	7.3	555.1	47	60	3	110
RAPID SURVEY	385.9	92.2	245.4	134.4	5.1	478.1	44	39	2	85
SO_2										
DETAILED INVENTORY	1,631.7	46.2	1,306.7	324.9	0	1,677.9	46	13	0	59
RAPID SURVEY	1,532.4	157.7	1,204.0	328.4	0	1,690.1	44	8	0	52

TABLE 1-3. AGGREGATION APPROACH - COMPARISON OF RAPID AND DETAILED EMISSION INVENTORIES/REGIONWIDE

most cases, it is less than 15%. This one exception is for the Cincinnati region where the particulate emissions from industrial processes are essentially totally absent and the particulate emissions from area sources are underestimated by some 60 tons per day. In general, however, the regionwide figures agree reasonably well.

In Table 1-4 and 1-5, these two regions are presented again, but individual sources are described in greater detail. In Table 1-4, major point sources for the Cincinnati region are presented. The specific sources being considered are listed in the left-hand column. The SO_2 and particulate emissions as described by the detailed and Rapid Survey inventories are listed in the four columns on the right-hand side. This table shows clearly that there are sizeable errors, especially in the powerplant emission rates, which are both positive and negative. For example, the Rapid Survey inventory includes an overestimate for the Beckjord SO_2 emission rate of 150 tons per day. Because of the magnitude of the emissions from powerplants, errors such as these mean that the level of accuracy in the remainder of the inventory is of little consequence. Looking at particulate emissions in this region, essentially the same situation is found and, in fact, in the case of the Miami powerplant, the Rapid Survey is in error by a factor of 10.

The situation is much better for St. Louis, at least insofar as the magnitudes of the emission rates are concerned. There is another difficulty, however, with the Rapid Survey inventories which is described in Table 1-5. In this table, the locational errors which were found in St. Louis are listed.

The differences in the X and Y coordinates (third and sixth columns in the table) should each be constant, i.e., a bias reflecting the different coordinate system origins used. The variation about the average X coordinate bias is about ± 1 km, assuming the large discrepancy between Portage Des Sioux and the remaining plants is due to a blunder. The Y coordinate bias is much closer to being constant. It is difficult to evaluate exactly what a 2 km error means in terms of ground-level concentrations. Since the Diffusion Model must be calibrated using air quality measurements taken at specific points in the region, and these locational errors could increase considerably the disparity between predicted and

	SO_2 Emissions (Tons/Day)		Particulate Emissions (Tons/Day)	
	Detailed Inventory	Rapid Survey	Detailed Inventory	Rapid Survey
Power Plants	961.33	905.23	225.28	50.24
• Tanners Creek	339.30	437.00	64.75	15.90
• Beckjord	452.52	308.60	29.62	20.31
• Miami	162.20	137.58	125.99	12.07
• Reading	1.10	.50	.09	.07
• Hamilton	6.21	21.55	4.83	1.89
Sorg Paper (Boiler)	4.03	3.70	12.50	12.40
Champion Paper (Boiler)	15.73	10.40	3.37	10.50
Proctor and Gamble (Boiler)	6.08	8.92	4.72	6.20
Dupont Sulfuric Acid	14.20	-	0	-
Philip Carey (Boiler)	2.38	3.13	7.35	7.89
General Electric (Boiler)	3.64	3.12	9.22	1.57
Interlake Steel (Electric Arc)	0	0	13.00	1.50
Armco Steel (Boiler)	11.77	82.20	5.48	68.50
Armco Steel (Open Hearth)	0	-	32.87	-

TABLE 1-4. AGGREGATION APPROACH - EMISSION INVENTORY COMPARISON
CINCINNATI MAJOR POINT SOURCES

PLANT	X_D*	X_R	(X_D-X_R)	Y_D	Y_R	Y_D-Y_R
MERAMEC	138.00	77.29	60.71	192.6	41.94	150.66
ASHLEY	151.21	88.94	62.27	218.6	68.20	150.40
CAHOKIA	150.6	88.86	61.74	215.0	64.46	150.54
VENICE	151.5	89.37	62.13	222.0	71.31	150.69
PORTAGE DES SIOUX	141.5	75.43	66.07	249.5	99.09	150.41

* X_D = detailed inventory X coordinate, kilometers

X_R = rapid survey X coordinate, kilometers

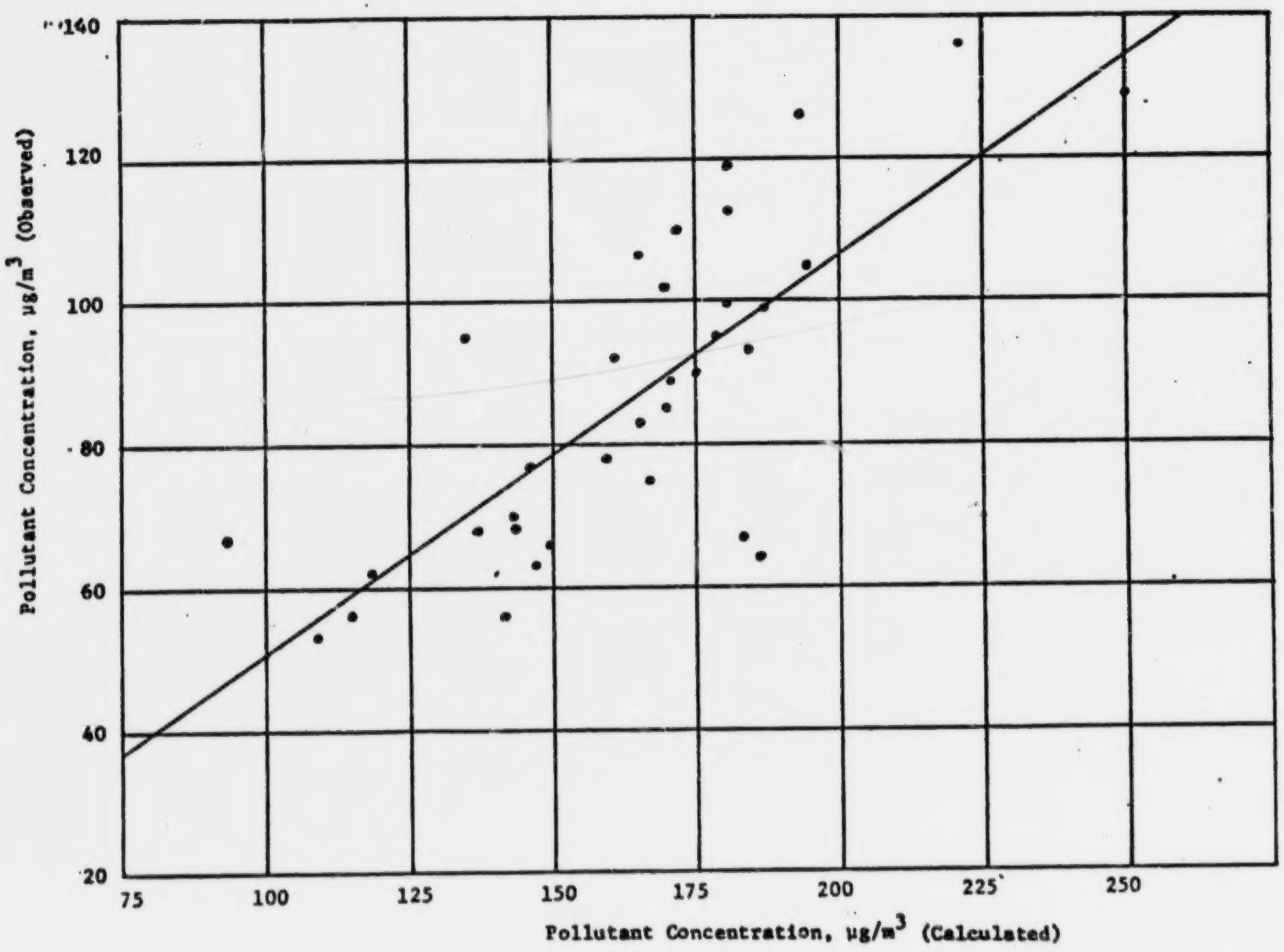
X_D-X_R = "conversion factor" between two coordinate systems

TABLE 1-5. AGGREGATION APPROACH - LOCATION OF ST. LOUIS POWERPLANTS

measured air quality, a poorer calibration is likely to result. There were other inaccuracies in the Rapid Survey inventories which affect air quality, e.g., stack height data. These inaccuracies are described in greater detail in Section 4.0 of this report.

The air quality implications of these inaccuracies in the Rapid Survey emission inventory are best revealed through calibration against measured data. As has been stated, the total regional emissions are about the same, but there are mislocated sources, and there are errors in the emission rates (both positive and negative) which could distort the regional air quality picture. Figures 1-1 and 1-2 display the regression lines which were obtained in calibrating the model predictions of particulate ground-level concentrations for the Cincinnati region. Figure 1-1 is the regression line using the detailed inventory; Figure 1-2 is that using the Rapid Survey inventory. As can be seen, the scatter when using the Rapid Survey inventory is much greater and the resulting lower regression coefficient gives much less confidence in the calibrated model results, i.e., 58% of the data variation is explained by the detailed regression line ($R^2 = 0.58$) as compared with 8% for the Rapid Survey regression line ($R^2 = .08$). Although this is the worst scatter obtained on any of the Rapid Survey runs, none of the regression lines came close to achieving the 95% confidence level.

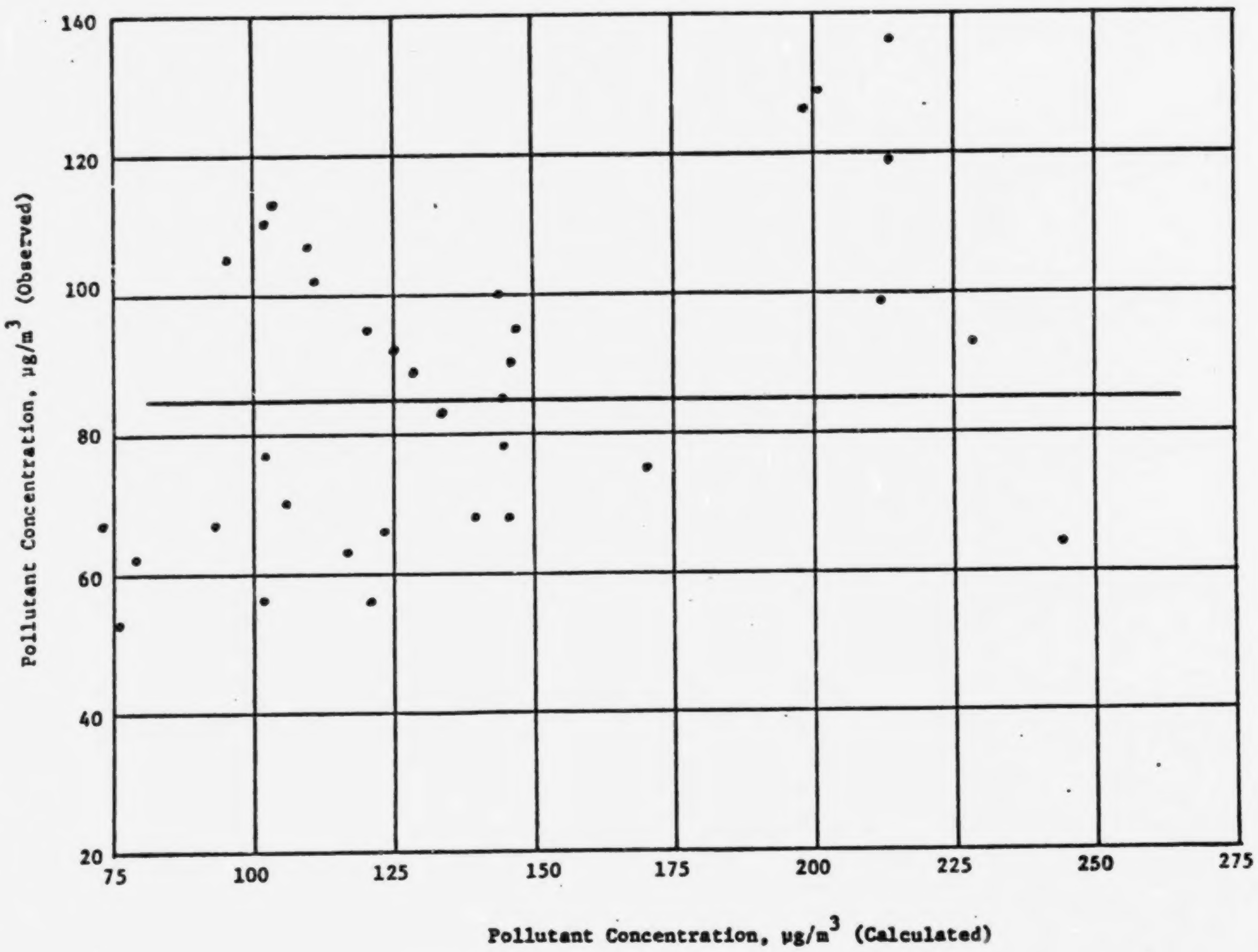
The total regional control costs in terms of dollars per year and in terms of control cost effectiveness in dollars per ton of pollutant removed are presented in Table 1-6. In the first column, the existing regional emissions given agree very well, as has been pointed out previously. In addition, the percentage reduction of emissions tend to agree between IPP results based on the detailed and Rapid Survey emissions inventories. The fact that the number of applicable and controlled sources is lower for the Rapid Survey is to be expected because of the nature of the emission inventory. However, the regional cost figures should be comparable, and as is shown in this table, they are not. In fact, there are differences of as much as a factor of 3 between control costs as predicted by the detailed inventory and those predicted by the Rapid Survey inventory.



Regression Coefficient, R = .762

For 95% Confidence Level, $R_{.95}$ = .335

FIGURE 1-1. AGGREGATION APPROACH - CINCINNATI PARTICULATE CALIBRATION DETAILED INVENTORY



Regression Coefficient, R = .282

For 95% Confidence Level, $R_{.95}$ = .335

FIGURE 1-2. AGGREGATION APPROACH - CINCINNATI PARTICULATE CALIBRATION RAPID SURVEY INVENTORY

	EXISTING REGIONAL EMISSIONS (TONS/DAY) POINT SOURCES	CONTROLLED REGIONAL EMISSIONS (TONS/DAY) POINT SOURCES	PERCENT REDUCTION OF EMISSIONS	REGIONAL COST $/YEAR	NO. SOURCES		COST EFFECTIVENESS $/TON OF POLLUTANT REMOVED
					APPL.	CON-TROLLED	
CINCINNATI							
PARTICULATES							
DETAILED INVENTORY	386.7	42.9	89	3,338,000	125	83	26.6
RAPID SURVEY	211.1	31.1	85	2,344,000	58	50	35.7
SO_2							
DETAILED INVENTORY	986.1	306.5	69	3,969,000	77	30	16.0
RAPID SURVEY	1,054.7	353.9	66	7,344,900	44	9	28.7
ST. LOUIS							
PARTICULATES							
DETAILED INVENTORY	446.8	75.6	83	12,693,000	110	85	93.7
RAPID SURVEY	385.9	55.9	86	4,526,100	85	63	37.6
SO_2							
DETAILED INVENTORY	1,631.7	361.2	78	20,187,100	59	46	43.5
RAPID SURVEY	1,532.4	550.8	64	22,688,000	52	41	64.71

TABLE 1-6. AGGREGATION APPROACH - COMPARISON OF 305(a) STRATEGY IMPACT ON POINT SOURCES

Because the Rapid Survey data on file at AQED was not originally intended to support IPP modeling, considerable effort was required to augment this data to the point where it could be used in the program. Approximately 1.5 man months was required for the data preparation for each of these two regions. In addition, some data which is essential for IPP was either not collected, or, because of the intended use of this data, was not recorded. Examples of specific data types that were difficult to recover are the following:

A. Fuel data: sulfur and ash content are both required, as well as the price for each fuel grade.

B. Plant Stack Data: including physical stack height and stack exit conditions.

C. Existing Control Equipment: particularly the efficiency for both SO_2 and particulates.

1.4.2 Extrapolation Approach

This procedure is based on the intensive study of a few regions to derive normalized control cost figures, e.g., dollars/kilowatt for powerplants, which could then be applied to national level output by industrial sector (e.g., installed capacity for powerplants). An evaluation of this procedure consisting of the following steps was conducted:

A. Tabulate control measures and costs for each region. The tabulation can be in terms of control costs per ton of pollutant removed. This tabulation is then examined for region-to-region and intra-regional differences and an attempt is made to isolate the causes for these differences.

B. Look at the components in the cost equation, i.e., the inputs that are needed to run the cost model, and determine how they vary from region to region, e.g., fuel costs vary considerably, perhaps a factor of two or three for a given fuel type across the regions. Other examples of cost input variations are device manufacturer's prices which don't change appreciably from region to region, and labor rates which can change by as much as 50%.

C. Determine the sensitivity of the computed control costs to variations in these input parameters.

Data from the IPP computer runs based on the detailed emission inventory (prepared to serve as the standard of comparison in evaluating the aggregation approach) were used, i.e., no special runs were required to evaluate the extrapolation approach.

Although the primary concern is with the estimation of control measure demand, control costs must be considered because of the strong interrelationship between demand and cost introduced by the IPP least-cost-alternative approach to control measure selection.

Control costs in terms of dollars per ton of pollutant removed for Cincinnati, St. Louis and Washington are presented in Table 1-7 for representative sources in each major source category. The fuel combustion category is represented by powerplants and industrial boilers, integrated iron and steel and petroleum refineries are included as examples of industrial process sources, and finally, municipal incinerators are included as representatives of solid waste disposal sources. In looking at the first row in this table, it is important to keep in mind that only electric powerplants have a uniform representation in all regions, i.e., all are relatively large regions, with total installed generating capacities on the order of 3,000 megawatts. Reading across the top row in this table, note that the costs for controlling particulates can vary by a factor of 8. Apparently, steam electric powerplants are a likely candidate for the first look at the details of the control cost calculation.

The IPP Cost Model output shows that most of the fuel combustion control measures consist of fuel substitutions, either coal-to-oil or coal-to-coal switches. Because of the number of fuel substitutions, an important variable in the calculation of the regional control is the cost of the substitute fuel. The variation in fuel prices (in terms of dollars per 10^6BTU) found across the three regions studied here is presented in Table 1-8. The prices included in this table are for fuels which meet the emission standard, i.e., 1% sulfur coal or 1.36% sulfur oil. As can be seen from this table, for a given fuel type, the price can vary by a factor of 2 from region to region; in addition, within a

	CINCINNATI		ST. LOUIS		WASHINGTON	
	PART.	SO_2	PART.	SO_2	PART.	SO_2
FUEL COMBUSTION						
STEAM ELECTRIC	21	16	34	46	164	18
INDUSTRIAL BOILERS	37	5	51	82	-	-
INDUSTRIAL PROCESS						
IRON & STEEL	32	-	191	-	-	-
PETROLEUM REFINERIES	-	-	293	-	-	-
SOLID WASTE						
INCINERATORS	30	-	36	-	32	-

TABLE 1-7. EXTRAPOLATION APPROACH - CONTROL COSTS -\$/TON REMOVED

- LOW SULFUR FUEL PRICES - \$/10^6BTU -

	CINCINNATI	ST. LOUIS	WASHINGTON
COAL	.24	.46	.29
OIL	.45	.49	.50

TABLE 1-8. EXTRAPOLATION APPROACH - STEAM ELECTRIC POWERPLANTS

given region, a factor of 2 variation is possible in going from one fuel type (coal) to another (oil). The fuel prices tabulated here were initially derived from Fuels for 50 Cities and were updated using, in the case of Cincinnati and Washington, information from local control officials and APCO. It is important to keep in mind that these represent prices which obtain at the current level of demand, and that they could be considerably in error in the presence of any widespread switching to low sulfur fuels. Reliance on static fuel prices is, incidently, a shortcoming which is common to all three of the techniques which are being studied here.

Given these variations in the prices for low sulfur fuels, the next step is to determine the sensitivity of the final computed control costs to these changes. For a typical 1,000 megawatt powerplant (e.g., Tanner's Creek, Cincinnati) a 10% change in the price of a substitute fuel results in a $930,000 change in the control cost for this one plant (an increase of 50%). This very large multiplier effect occurs because of the impact of incremental fuel costs, i.e., the additional cost of replacing the original fuel with a substitute fuel of lower sulfur content. For a region like Cincinnati, with close to 3,000 megawatts of installed capacity, a 10% fuel price change would then imply a 2 million dollar change in predicted control costs. Because the nearly constant costs associated with wet limestone injection, relative price changes of this magnitude can cause a significant shift in the control measure demand. Thus, this very high sensitivity when coupled with the variation in fuel prices displayed in Table 1-7, indicates that powerplants must be treated individually, i.e., region-to-region and intra-regional variation in fuel prices must be considered.

1.4.3 305(a) Approach

In coming up with the national level control cost estimates presented in the 305(a) report, background data was collected which should allow the tabulation of the corresponding control measure demand, i.e., the types of control measures assumed for each industry category are known and the costs incurred are known; consequently, it should be possible to compute the number of devices or the quantity of low sulfur fuel which would be required. A procedure for this "back-calculation" was developed and applied to the three regions for which the detailed emission inventories are available. The control measure demand and cost estimates were then evaluated by comparing the 305(a) results with those obtained using detailed emission inventories. The comparison was made on the basis of the predictions of control measure demand and cost and the structure of the cost equations.

Because the importance of major fuel combustion sources has already been noted (Section 1.3 above), these sources were emphasized in this comparison. A detailed comparison of costs for controlling powerplants in Cincinnati is presented in Table 1-9. According to the IPP results (first row of the table) 3.9 million dollars are required for powerplant control. Note that the IPP program is set up to select the least-cost alternative available to each source subject to control. In the second line of this table, the 1970 305(a) report prediction that 31 million dollars would be required to control Cincinnati powerplants is listed; here it is assumed that all powerplants will switch to low sulfur oil. The last line shows that the 1971 305(a) report forecasts a 8.4 million dollar control cost, with all powerplants going to wet limestone injection. All of these control cost projections are based on essentially the same fuel price information; consequently, there must be another reason for the tremendous difference. In Table 1-10 the most likely cause of the difference, i.e., the assumptions made in selecting control measures- is evaluated by using the IPP Cost Model and applying the 305(a) 1970 and 1971 assumptions, i.e., switch to low sulfur oil and installation of wet limestone injection, respectively. As shown in this table, IPP predicts a cost of 35.7 million for the switch to low sulfur oil. This is compared with an estimate from the 305(a) report of 31 million. For the 1971 assumption IPP predicts a switch-to-wet-limestone control cost of 9.6 million dollars, as compared with 8.4 million in the 305(a) report, indicating the importance of the assumption that is made regarding control measure selection. The region-to-region variation in fuel price has been shown to be important and is already being considered in the 305(a) approach, at least for industrial boilers. For powerplants, however, the availability of lower cost fuel substitution control measures is not being considered, i.e., every powerplant is assumed to switch to wet limestone injection, even though it might be possible to use much cheaper low sulfur coal. The 3.9 million projection by IPP (Table 1-9) consisted primarily of switches to low sulfur coal. For this particular region, low sulfur coal is not only

POWERPLANTS - CINCINNATI

SOURCE OF PREDICTION	CONTROL MEASURE	POWERPLANT CONTROL COST (10^6 $)
IPP	LEAST COST TO INDIVIDUAL SOURCE	3.9
305(A) REPORT - 1970	SWITCH TO LOW SULFUR OIL	31.0
305(A) REPORT - 1971	WET LIMESTONE	8.4

TABLE 1-9. 305(a) APPROACH - DEMAND/COST PREDICTIONS - POWERPLANTS

APPLY 305(A) RULES FOR CONTROL MEASURE SELECTION TO IPP COST MODEL RESULTS

SOURCE OF PREDICTION	CONTROL MEASURE	POWERPLANT CONTROL COST (10^6 \$)
IPP	SWITCH TO LOW SULFUR OIL	35.7
305(A) 1970	SWITCH TO LOW SULFUR OIL	31.0
IPP	WET LIMESTONE	9.6
305(A) 1971	WET LIMESTONE	8.4

TABLE 1-10. 305(a) APPROACH - DEMAND/COST PREDICTIONS - POWERPLANTS - IPP USING 305(a) CONTROL MEASURES

much cheaper than residual oil, it is probably the only fuel that will be available. Residual fuel oil would have to be imported on the Ohio River, generating an additional increment in barge traffic which would push the total traffic level beyond that which the river can accommodate.

Industrial boilers are another significant source of particulate and SO_x emissions. For the Cincinnati region, this category of fuel combustion source was examined to determine if the same phenomenon as has been found in the powerplant estimating procedure existed. In Table 1-11, the first line shows the IPP prediction of $800,000 for control of industrial boilers in the Cincinnati region. Here, the least cost alternative for each boiler, for which the original fuel sulfur content is greater than 1 percent, is selected. The second line gives the 305(a) report estimate of 8 million dollars with all sources switching to low sulfur fuel. Again, if the 305(a) control measure assumption is applied to the IPP Cost Model results, the resulting IPP estimate of 8.5 million dollars is very close to that in the 305(a) report. The problem inherent in allocation of national fuel use figures to individual regions on the basis of population (as is done in the 305(a) report) shows up in this table as well. Most of the large industrial boilers in Cincinnati already burn 1 percent sulfur fuel and would not, in fact, have to switch fuels.

1.4.4 Conclusions and Recommendations

The Aggregation Approach to estimating national level control measure demand, which was known at the outset to be theoretically suitable, is not recommended at present because of inadequacies in the existing Rapid Survey data. This data was collected to serve as input to a diffusion model in the designation of air quality control regions, and does not give adequate accuracy even when augmented to meet the more comprehensive input requirements of IPP.

The Extrapolation Approach looks unattractive because it can't account for region-to-region variations, primarily those in fuel prices.

The 305(a) Approach includes variations in fuel prices, but since all combustion sources are assumed to select only one control measure (local least-cost alternatives are not available), it does not give sufficient resolution of fossil fuel demand. The assumption that all powerplants are going to use wet limestone injection may give an indication of what control costs are going to be, but it is not adequate when

- INDUSTRIAL BOILERS - CINCINNATI

SOURCE OF PREDICTION	CONTROL MEASURE	INDUSTRIAL BOILER CONTROL COST (10^6 $)
IPP	LEAST COST TO INDIVIDUAL SOURCE	0.8
305(A) REPORT, 1971	ALL SWITCH TO LOW SULFUR OIL	7.9

- APPLY 305(A) RULES:

SOURCE OF PREDICTION	CONTROL MEASURE	INDUSTRIAL BOILER CONTROL COST (10^6 $)
IPP	ALL SWITCH TO LOW SULFUR OIL	8.5
305(A) REPORT, 1971	ALL SWITCH TO LOW SULFUR OIL	7.9
IPP	THOSE > 1% S SWITCH TO OIL	1.9

TABLE 1-11. 305(a) APPROACH - DEMAND/COST PREDICTIONS - INDUSTRIAL BOILERS

trying to estimate fuel demand, since many powerplants will surely select low sulfur coal or residual fuel oil, if either of these options is available and is cheaper than flue gas desulfurization.

The recommended approach for estimating control measure demand, given the data base which is currently available, consists of combining a limited IPP modeling effort on powerplants and major industrial boilers, with data generated using the 305(a) Approach for all other source categories.

It is recommended that the IPP Control-Cost and Strategy Models be run on the individual powerplants using the 305(a) emission standards and local fuel prices, so that the least-cost alternative will be selected at each site. The IPP Atmospheric Transport Model would not be used (because of lack of data), so that it would have to be assumed that the emission standards used would achieve the air quality standards, except for some major AQCR's where the actual local emission standards could be used (if they were from an approved Implementation Plan).

For powerplants, various fuel switches should be considered, along with wet limestone injection, as control measure alternatives. More detail will be needed on fuel prices, and some technique for accounting for the effects of increased fuel demand on prices will be required. The two control cost estimates in the Cincinnati powerplant example used above probably bound the variation in control cost due to demand generated changes in fuel prices. The cost associated with many switches to low sulfur coal is a lower bound, since static fuel prices are used which would be unrealistic in the event of widespread switching to low sulfur fuel on the national level. The 305(a) estimate (assumes most select wet limestone injection) provides an upper bound, since if fuel prices exceeded this level there would be switching to the wet limestone devices. In the fuels analysis, it is also important to include some consideration of the availability of fuels, especially low sulfur coal.

The Federal Power Commission has collected detailed information on every powerplant in the nation (Form 67), which could be used to update and augment the existing emission inventory.

It won't be possible to determine the level of control required on powerplants in each individual region, since this would require diffusion modeling of every region in sufficient detail that the relative impact, and, consequently, the degree of control required, could be identified It has already been pointed out that the existing emission inventory data is inadequate for this task.

The improvement which would give the next best return on resources invested would be a detailed emission inventory on major industrial boilers. These boilers could then be analyzed in the same manner as described above for powerplants.

Control measure demand predictions for the remaining industrial process and solid waste disposal sources could be derived using the 305(a) Approach.

1.5 305(a) EMISSION STANDARDS EVALUATION

There is an important assumption implicit in all three of the control demand estimation techniques which must be evaluated, i.e., that the emission standards that have been imposed (Table 1-1) will be adequate to meet local air quality standards. In Table 1-12, for each of the three regions, an indication is given where the particulate and SO_2 air quality standards have been met. A standard of 65 micrograms per cubic meter was selected for both pollutants for this evaluation. This is probably a good figure for particulates, but may tend to be somewhat higher than the air quality standards being adopted for sulfur dioxide.

Of the total of six pollutant/region combinations studied, air quality equal to the standard was achieved in only three, where meeting the standard was interpreted to mean that no point in the region may exceed the standard. For each pollutant/region combination in this table, the margin by which the standard is met is indicated in parentheses (in $\mu g/m^3$); a negative sign means the standard was exceeded.

In order to determine the incremental cost incurred in achieving the air quality standards, additional runs were made for those regions where air quality was not achieved, i.e., St. Louis and Washington. The emission standards described in Table 1-1 were applied at increasing levels of stringency until the air quality standards were met. Increased

	Particulates*	SO_2*
Cincinnati	YES (5)**	YES (<1)
St. Louis	NO (-50)	YES (5)
Washington	NO (-15)	NO (-35)

* - Air Quality Standard of 65 μg/m^3 Assumed

** - Margin by which Standard is Met, μg/m^3 (negative sign means standard exceeded)

TABLE 1-12. ACHIEVING AIR QUALITY STANDARDS USING 305(a) EMISSION STANDARDS

stringency was achieved by dividing the 305(a) allowable emissions by 2, i.e., predictions of air quality and control costs were made using 305(a)/2, 305(a)/4, etc. In St. Louis, meeting air quality standards required an increment in costs of 50% over the 305(a) control costs, corresponding to allowable emissions which were scaled to 305(a)/4. Washington, D.C. where neither air quality standard was achieved, required 1000% and 180% cost increments to meet the standards for particulates and SO_2, respectively; allowable emission rates for both pollutants were scaled to 305(a)/2. The very large increment in control costs for Washington particulates is due to the fact that the unscaled 305(a) emission standards had virtually no effect, and, consequently, a very low control cost. Ignoring this one data point, it appears that meeting air quality standards, rather than simply complying with uniformly applied emission standards, can have a significant effect on predicted control costs (50-200%).

To further evaluate the impact of the 305(a) emission standards on air quality, Figures 1-3, 4 and 5 were prepared. Increasing levels of air quality standards are plotted on the horizontal axis in these figures; the number of receptors which exceed the air quality standard is plotted on the vertical axis. This allows evaluation of air quality standards other than the 65 $\mu g/m^3$ level used in this study. Although the receptor grid spacing is not uniform, the number of receptors which exceed a standard is roughly proportional to the area over which the standard is exceeded.

1.6 USE OF RAPID SURVEY AS IPP INPUT

Although the existing Rapid Survey data is inadequate to support the Aggregation Approach, some modifications to the way in which the technique is applied should make the data useful for IPP modeling.

For many regions, 6 to 12 large sources emit 75% or more of the regional totals for particulates and SO_2. This group, which will usually include powerplants, integrated iron and steel plants, and perhaps a few others, will prove to be substantially more important, in terms of total emissions, than the many small fuel combustion, industrial process, and solid waste disposal sources which make up the remainder of the point source emission inventory. An illustration of the importance of these

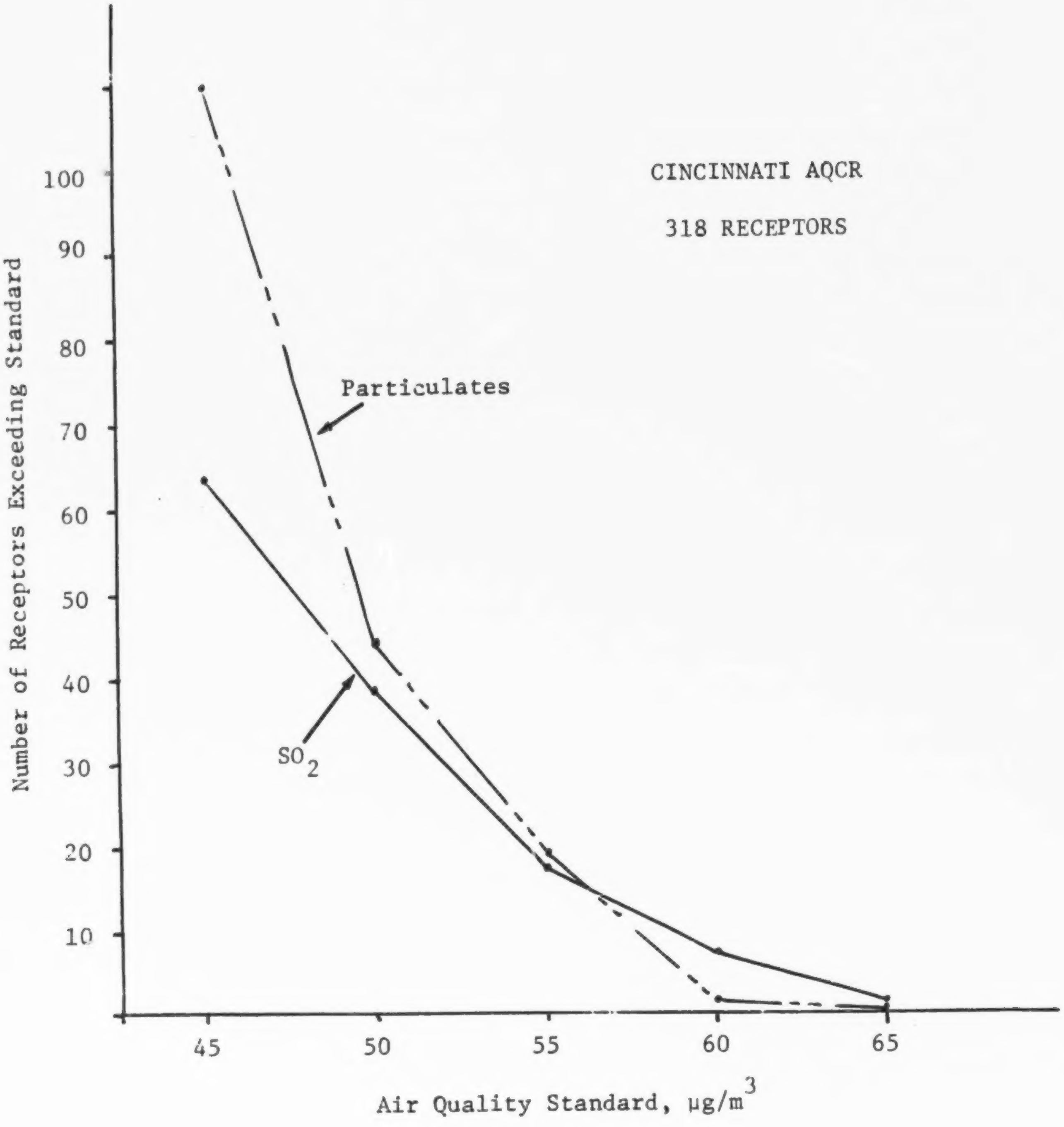


FIGURE 1-3. IMPACT OF 305(a) EMISSION STANDARDS ON AIR QUALITY STANDARDS - CINCINNATI

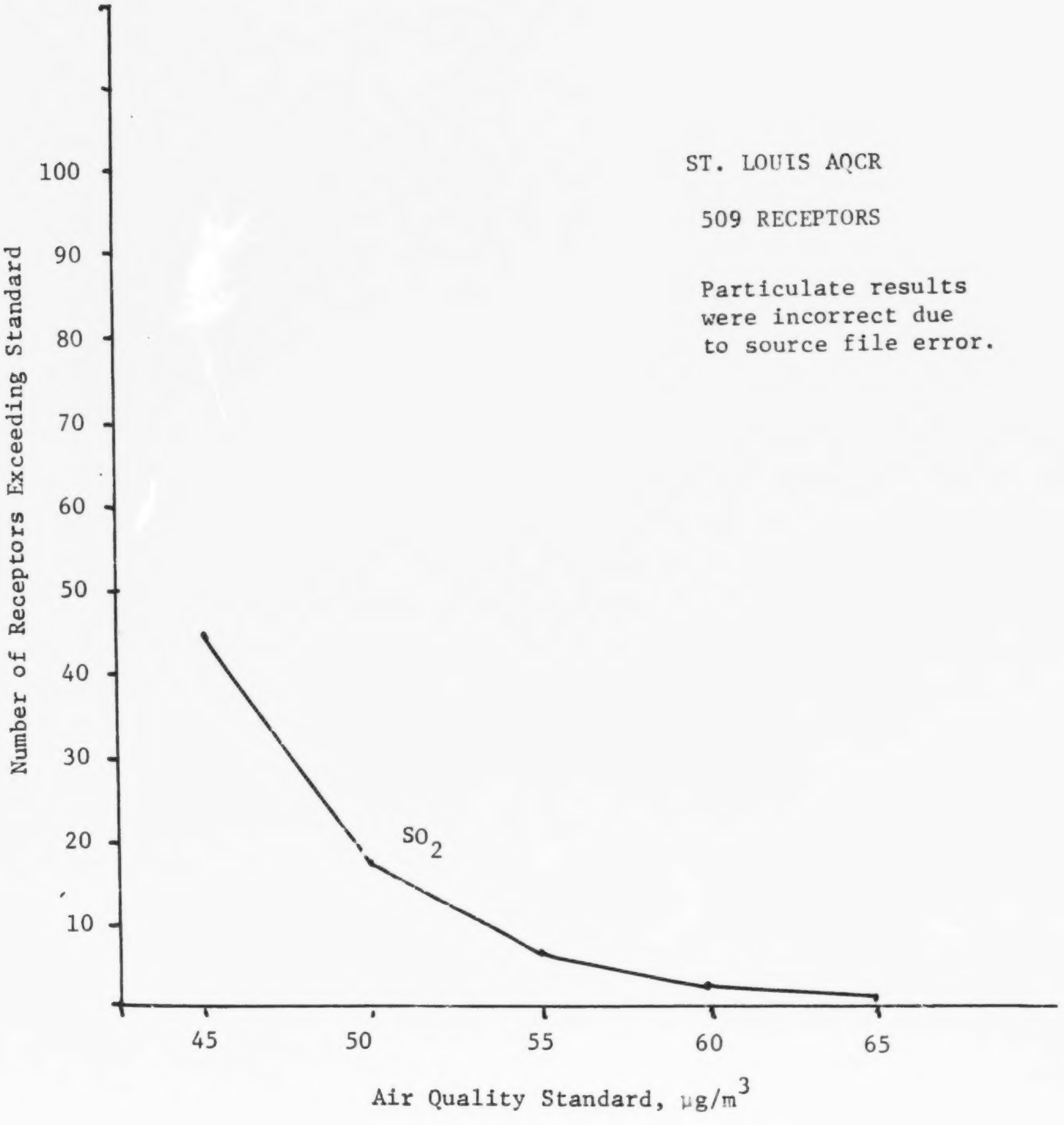


FIGURE 1-4. IMPACT OF 305(a) EMISSION STANDARDS ON AIR QUALITY STANDARDS - ST. LOUIS

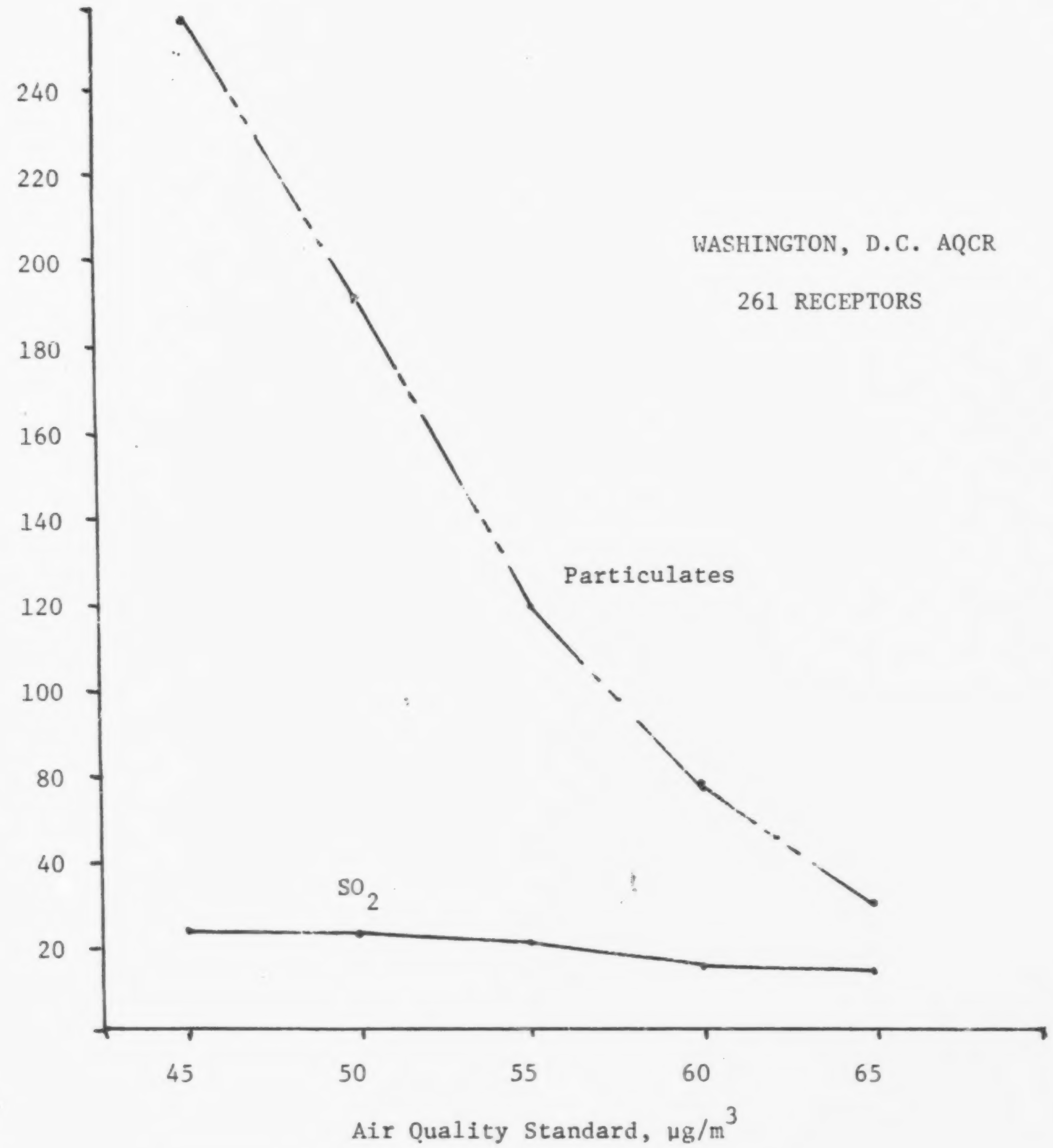


FIGURE 1-5. IMPACT OF 305(a) EMISSION STANDARDS ON AIR QUALITY STANDARDS - WASHINGTON, D.C.

major point sources in the Ohio portion of the Metropolitan Cincinnati Interstate Air Quality Control Region is presented in Table 1-13. An inspection of this table reveals that a total of 7 sources - 2 powerplants, 2 paper companies, a steel plant, a chemical plant, and a manufacturing plant - provide 85% of the total SO_2 emissions and 68% of the total particulate emissions in the area. A small additional effort at increasing the accuracy and level of detail for these few sources will have a substantial effect on improving the accuracy of IPP results derived from a Rapid Survey emissions inventory.

Because the existing Rapid Survey data was collected for another purpose, values for many important variables were either not collected, or were not recorded because they were only intermediate quantities in terms of the original purpose for collecting the data. For an IPP data base, however, documentation of sources of information, assumptions, and methods of calculation is very important.

Finally, a handbook which would give values for exit conditions, stack heights, process rates, etc., which reflect industry practice, would allow any gaps in the emission inventory to be filled. If this data, used on smaller sources, is combined with the more intensive investigation of the large sources mentioned above, an emission inventory adequate for IPP modeling should result.

TABLE 1-13. MAJOR POINT SOURCES IN THE OHIO PORTION OF MCIAQCR (Reference 8)

	Sulfur Oxides (tons/day)	% of Total	Particulates (tons/day)	% of Total
OHIO				
Total Emissions, All Sources	670.55	100.00	333.85	100.00
Andersonville Dump	0.17	.03	6.85	2.05
Armco Steel Corp.	11.93	1.78	50.62	15.16
Center Hill Incinerator	0.58	.09	1.62	.49
Champion Paper Co.	15.73	2.35	3.37	1.01
Cincinnati G&E Co. (Beckjord Station)	368.59	54.97	28.12	8.42
Cincinnati G&E Co. (Miami St. Station)	162.20	24.19	125.99	37.74
Colerain Dump	0.17	.03	6.85	2.05
Container Corp. of America	1.90	.28	1.50	.45
Crystal Tissue Co.	1.56	.23	2.63	.79
Diamond National Corp. (Lockland Plant)	5.42	.81	1.21	.36
Diamond National Corp. (Middletown Plant)	4.42	.07	1.64	.49
Dunbar Incinerator	0.14	.02	1.24	.37
E.I.DuPont de Nemours Co., Inc.	14.20	2.12	--	
Emery Industries Inc.	3.50	.52	2.80	.84
Ford Motor Co. (Sharonville Plant)	1.30	.19	3.30	.99
Formica Corp.	3.67	.55	--	
Fox Paper Co.	1.28	.19	1.43	.43
General Electric Co.	3.64	.54	9.22	2.76
Gulf Oil Corp.	2.90	.43	0.24	.07
Hamilton Municipal Power Plant	6.21	.93	4.99	1.49
Hilton Davis Chem. Co.	2.53	.38	0.11	.03
International Chem. Co.	2.59	.39	--	

TABLE 1-13. MAJOR POINT SOURCES IN THE OHIO PORTION OF MCIAQCR (Reference 8) (Continued)

	Sulfur Oxides (tons/day)	% of Total	Particulates (tons/day)	% of Total
National Lead Co. of Ohio	1.56	.23	1.05	.31
Philip Carey Corp.	2.38	.35	7.35	2.20
Procter and Gamble Company	6.08	.91	5.22	1.56
Reading Power Plant	1.10	.16	0.09	.03
Sorg Paper Co.	4.03	.60	12.50	3.74
Stearns and Foster Co.	1.87	.28	1.11	.33
West Fork Incinerator	0.30	.04	1.84	.55

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2.0 INTRODUCTION

The Implementation Planning Program is now completed and has been installed on the APCO computer in Durham, North Carolina. The primary purpose in developing this program was to provide a tool which could be used in solving the regional air resource management problem. IPP has been used extensively for this purpose by States, local control agencies, universities and private contractors throughout the country. The purpose of this study is to determine if IPP can be used to answer some more-or-less interrelated questions which are not a part of the air resource management problem. Specifically, the study had the following three objectives:

A. To evaluate three approaches to the estimation of the national demand for air pollution control measures generated in response to the Air Quality Act.

B. To investigate the air quality implications of the enforcement of those emission standards outlined in the 305(a) Cost of Clean Air Report to Congress.

C. To determine the feasibility of upgrading currently available Rapid Survey emission inventories so that they may be utilized in the Implementation Planning Program computer model.

The three demand estimating approaches evaluated under objective A are:

1) Extrapolation Approach. The extensive study of control measure demand in a small number of regions and extrapolation results to the national level.

2) Aggregation Approach. The generation of control measure demand in a large number of regions (representing a large proportion of the total nation) and aggregation of the results to the national level.

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3) 305(a) Approach. The utilization of existing Economics of Clean Air (305(a)) background cost data to derive national control measure demands.

Most of the resources of the study were committed to objective A and more specifically to the evaluation of the Aggregation Approach; that is, the primary objective of the study is to determine whether or not running all the regions now covered by emission inventory data in the Division of Air Qualtiy and Emissions Data (AQED) files through the IPP is worthwhile. Thus, the main activity in the study was basically a data evaluation exercise, since it was known at the outset that (theoretically) the Aggregation Approach should work. By properly structuring the work required to answer this question, the questions associated with objectives A 1), B and C can also be answered with very little additional effort. For example, it is necessary to run a regional analysis using the best available emissions inventory data to provide a standard of comparison for the evaluation of the Rapid Survey data. By using the emission standards outlined in the 305(a) report in running these regional analyses, it is possible to answer the question regarding the air quality impact of the 305(a) emission standards at the same time. Similarily, the feasibility of using the Rapid Survey technique to provide a data base for the Implementation Planning Program can be examined as part of the process of evaluating the existing Rapid Survey data for use in IPP.

Objectives B and C are not addressed specifically in separate sections in this report. Rather, they are discussed at the point at which they naturally occurred in the course of the analysis. The air quality question (objective B) is answered in Section 3.0 where the description of the detailed inventories and the IPP results based on these inventories is presented. The feasibility of using the Rapid Survey technique, which is a logical outgrowth of the work done in upgrading the existing Rapid Survey data to run IPP, is discussed in Section 4. A brief description of the content of each section is presented below.

In Section 3.0, Extrapolation Approach, the discussion of the detailed inventory results is presented. The original intent in running these regional analyses was to cover four regions: Cincinnati, Philadelphia, St. Louis and Washington. Problems with computer tapes generated in running the Philadelphia model, however, made future processing for this region impossible. Consequently, this analysis proceeded with just the three regions. In this section the 305(a) strategy, which is simply the collection of emission standards outlined in the 305(a) report, is introduced and its impact in terms of applicable sources, controlled sources, cost, cost-effectiveness and device demand is presented. The discussion of the ability of the 305(a) emission standards to achieve air quality standards is also included in this section. In addition, the effects of more stringent levels of 305(a) emission standards where these are required to meet air quality standards are presented.

In Section 4, Aggregation Approach, the discussion of the Rapid Survey results is presented. Of the three regions which remained in the detailed inventory regional analyses group, only two (Cincinnati and St. Louis) were covered by the Rapid Survey data in the AQED files, so at this point the study sample was reduced to two regions. The description of the Rapid Survey technique, the development of the IPP data file by augmenting the Rapid Survey data, and the discussion of errors in the Rapid Survey data is presented in this Section. The impact of the 305(a) strategy is again described; in this case, as predicted by running IPP using the Rapid Survey data base. Considerable detailed discussion is presented in comparing the results of the control group (i.e., the detailed inventory runs) and the Rapid Survey results. This discussion is presented in terms of a direct emission inventory comparison, an air quality estimate comparison and a direct comparison of the 305(a) strategy impact.

The 305(a) Approach is described in Section 5. A description of the non-modeling procedure is presented, and its relationship to the other two approaches (which both involve modeling) is described. The basic data used in the 305(a) Approach is presented for all four regions in this section, along with the prediction of control measure demand implied by this cost data.

More data has been presented in this report than was used in the evaluation of control measure estimation alternatives. Conclusions have been drawn and recommendations have been made (see Section 1.0) largely on the basis of the results when each of these three candidate approaches is used on large fuel combustion sources. However, all of the technical backup data has been included in this report, since it can provide a data base for additional analyses.

3.0 EXTRAPOLATION APPROACH

The Extrapolation Approach to the prediction of national pollution control costs and control measure demand involves a detailed analysis, on an industry-by-industry basis, of the effects of a particular abatement strategy on a small number of regions. Extrapolation to national level predictions is achieved by scaling with the ratio of such variables as total emissions, total production, kilowatt-hours of power generated (in the case of steam/electric plants), and others. An overly simplified example of this type of extrapolation is the following:

$$\text{Total National Cost of Control for Steam/Electric Plants}$$

$$\cong (\text{Control Cost in Cincinnati}) * \frac{\text{National KW-Hrs.}}{\text{Cincinnati KW-Hrs.}}$$

Since linearity is not likely to hold in these extrapolations, a minimum of three points is necessary to produce an accurate estimate. In fact, the probability of fluctuations in control costs due to factors difficult to account for in this type of analysis--for instance, the presence of one very large plant with special control problems causing industry costs to be high in relation to the value of the assigned variable--demands that additional points be added as they become available, i.e., as additional regions are run on IPP. An additional problem with the use of only these three regions is that many industry groups are either not represented or else are represented by only one or two sources, which is certainly an insufficient number for extrapolation purposes.

It should be noted that the above difficulties with this approach were well known before modeling was begun. However, this technique has been suggested on a number of occasions, and an investigation into the magnitude of these problems was deemed to be useful. No additional model runs were necessary to implement this analysis, however, since the detailed runs were necessary to provide a comparison with the Rapid Survey runs described in Section 4, and also to provide an estimate of the adequacy of the 305(a) regulations with respect to achieving air quality standards.

Three detailed inventories--those of Washington, D.C., Cincinnati, and St. Louis--were available for the study. As described in Section 2, these regions were run through the IPP model using the Cost of Clean Air 305(a) emission standards; where compliance with a 65 $\mu g/m^3$ air quality standard was not achieved, the standards were made uniformly more strict (by lowering the allowable emissions of the three standards by some factor). Sections 3.1 through 3.3 describe the results of these strategy runs.

3.1 RESULTS OF POLLUTANT CONTROL STRATEGIES - INDUSTRY COSTS, EMISSIONS, AND AIR QUALITY

Tables 3-1 through 3-9 describe the effects of the various emission control strategies applied to the three AQCR's investigated in this study. Figures 3-1 through 3-9 are plots of "isopleths," or lines of constant air quality for each of the nine strategies. These plots indicate the extent to which each of the strategies satisfy the specified air quality goal of 65 $\mu g/m^3$ for SO_2 and particulates.

The 305(a) strategy for SO_2 and particulates is defined in Section 2 of this report. The designation "305(a)/2" defines a strategy where the allowable emissions are one-half those specified in Section 2. During the course of this study, additional strategies based on the 305(a) standards were investigated, but the results would not significantly add to those presented here and are therefore not discussed.

3.1.1 Cincinnati AQCR

The yearly cost* of implementing the 305(a) emission strategy in the Cincinnati AQCR is \$3,969,000 for SO_2 and \$3,338,000 for particulate control. By far the greatest component of this cost, especially in the case of SO_2, is the combustion of fuels.

Steam/electric powerplants require the major proportion of these funds and, in addition, account for 89 percent of the SO_2 and 58 percent of the particulate point source emissions in the region. After controls have been installed, these percentages drop to 79 and 48 percent of the new (controlled) total, respectively, mainly because:

- The powerplants were using lower grade fuel than the other combustion sources in the region.

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*As discussed in Appendix B, these costs exclude agency and small source costs.

TABLE 3-1 EFFECTS OF REGULATIONS; CINCINNATI 305(a) SO_2 STRATEGY(DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON **REMOVED**
o Steam/Electric	17	13	3,794	876.4	303.6	242.8	16.4
o Commercial/Institutional Boilers	12	1	-3	4.6	5.1	4.6	-133.
o Industrial Boilers	42	13	52	81.5	145.7	52.0	4.
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	2	0	0	.2	2.0	.2	-
o Grey Iron	0	0	0	0	0	0	-
o Non-Ferrous Metals	0	0	0	0	0	0	-
o Sulfuric Acid	3	3	126	20.	1.5	4.1	21.1
o Oil Refineries	1	0	0	2.9	1.5	2.9	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	0	0	0	0	0	0	-
o Fuel Combustion	71	27	3,843	962.5	454.4	299.4	15.9
o Industrial Process	6	3	126	23.5	5.0	7.	21.1
o Solid Waste Disposal	0	0	0	0	0	0	-
o TOTAL	77	30	3,969	986.0	459.	306.5	16.0

TABLE 3-2 EFFECTS OF REGULATIONS; CINCINNATI 305(a) PARTICULATE STRATEGY (DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON REMOVED
o Steam/Electric	17	14	1,577	223.9	37.0	20.4	21.2
o Commercial/Institutional Boilers	12	10	37	2.1	1.3	1.0	100.2
o Industrial Boilers	42	38	795	70.0	16.4	10.7	36.7
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	12	8	671	63.3	6.1	5.7	31.9
o Grey Iron	6	0	0	2.0	.3	2.0	-
o Non-Ferrous Metals	3	0	0	.4	.1	.4	-
o Sulfuric Acid	1	1	15	.2	.1	.0	212.0
o Oil Refineries	1	0	0	.2	.7	.2	-
o Asphalt Batching	4	4	13	1.2	.1	.1	33.4
o Cement	4	0	0	.8	1.1	.8	-
o Grain	0	0	0	0	0	0	-
o Varnish	2	0	0	.5	.3	.5	-
o Other	1	0	0	.3	.1	.3	-
o Fuel Combustion	71	62	2,409	296.0	54.8	32.1	25.0
o Industrial Process	34	13	699	68.3	9.0	9.4	32.5
o Solid Waste Disposal	20	8	231	22.4	4.6	1.4	30.2
o TOTAL	125	83	3,338	386.7	64.3	42.9	26.6

TABLE 3-3 EFFECTS OF REGULATIONS; ST. LOUIS 305(a) SO_2 STRATEGY (DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON REMOVED
o Steam/Electric	10	10	13,717	1,030.4	346	223.7	45.6
o Commercial/Institutional Boilers	4	4	315	13.6	3.7	0	63.4
o Industrial Boilers	32	27	5,886	262.8	126.1	66.6	82.2
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	1	0	0	17.3	2.7	17.3	-
o Grey Iron	0	0	0	0	0	0	-
o Non-Ferrous Metals	1	1	*	232.0	10.5	5.8	*
o Sulfuric Acid	6	4	270	35.7	80.4	8.0	26.6
o Oil Refineries	4	0	0	39.8	85.1	39.8	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	1	0	0	.1	19.7	.1	-
o Fuel Combustion	46	41	19,917	1,306.8	475.8	290.3	53.7
o Industrial Process	13	5	270	324.9	198.3	70.9	2.9 *
o Solid Waste Disposal	0	0	0	0	0	0	-
o TOTAL	59	46	20,187	1,631.7	674.5	361.2	43.5

*Model predicts a profit from sale of sulfuric acid for one large source.

TABLE 3-4 EFFECTS OF REGULATIONS; ST. LOUIS 305(a) PARTICULATE STRATEGY (DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON **REMOVED**
o Steam/Electric	10	8	2,118	188.0	35.2	18.5	34.2
o Commercial/Institutional Boilers	4	4	124	5.2	.8	.4	71.2
o Industrial Boilers	33	28	1,976	116.2	21.1	9.9	50.7
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	7	4	555	11.9	3.9	3.9	190.7
o Grey Iron	4	4	27	2.6	.3	0	29.2
o Non-Ferrous Metals	6	3	520	2.2	1.0	.6	1,381.8
o Sulfuric Acid	5	5	293	5.1	1.5	.6	178.1
o Oil Refineries	5	4	946	10.1	3.9	1.3	292.5
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	4	2	153	10.0	1.6	5.7	96.6
o Grain	15	15	4,469	50.4	2.4	.6	245.7
o Varnish	0	0	0	0	0	0	-
o Other	14	6	1,428	10.1	3.9	5.5	837.7
o Fuel Combustion	47	40	4,218	309.4	57.1	28.8	41.2
o Industrial Process	60	43	8,390	102.5	18.5	18.2	274.5
o Solid Waste Disposal	3	2	86	7.3	2.1	.8	36.5
o TOTAL	110	85	12,693	419.1	77.7	48.4	93.7

TABLE 3-5 EFFECTS OF REGULATIONS; ST. LOUIS 305(a)/4 PARTICULATE STRATEGY (DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON **REMOVED**
o Steam/Electric	10	10	6,634	188.0	8.8	4.3	98.9
o Commercial/Institutional Boilers	4	4	163	5.2	.2	.0	86.4
o Industrial Boilers	33	32	2,797	116.2	5.3	2.6	67.4
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	7	5	983	11.9	1.0	3.9	364.7
o Grey Iron	4	4	27	2.6	.1	0	29.2
o Non-Ferrous Metals	6	5	757	2.2	.4	.5	1,249.6
o Sulfuric Acid	5	5	404	5.1	1.0	.2	224.4
o Oil Refineries	5	4	949	10.1	0	1.2	291.3
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	4	2	153	10.0	.4	5.7	96.6
o Grain	15	15	4,471	50.4	.6	.5	245.4
o Varnish	0	0	0	0	0	0	-
o Other	14	7	1,473	10.1	1.0	5.0	793.1
o Fuel Combustion	47	46	9,594	309.4	14.2	6.9	86.9
o Industrial Process	60	47	9,217	102.5	4.7	17.2	297.8
o Solid Waste Disposal	3	2	145	7.3	.5	.3	56.6
o TOTAL	110	95	18,956	419.1	19.5	24.3	131.7

TABLE 3-6 EFFECTS OF REGULATIONS; WASHINGTON, D. C. 305(a) SO_2 STRATEGY (DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON REMOVED
o Steam/Electric	22	8	1,732	492.2	328.9	234.1	18.4
o Commercial/Institutional Boilers	120	1	22	47.2	66.9	46.9	243.3
o Industrial Boilers	9	0	0	2.6	3.6	2.6	-
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	0	0	0	0	0	0	-
o Grey Iron	0	0	0	0	0	0	-
o Non-Ferrous Metals	0	0	0	0	0	0	-
o Sulfuric Acid	0	0	0	0	0	0	-
o Oil Refineries	0	0	0	0	0	0	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	0	0	0	0	0	0	-
o Fuel Combustion	151	9	1,754	542	399.5	283.6	18.6
o Industrial Process	0	0	0	0	0	0	-
o Solid Waste Disposal	0	0	0	0	0	0	-
o TOTAL	151	9	1,754	542	399.5	283.6	18.6

TABLE 3-7 EFFECTS OF REGULATIONS; WASHINGTON, D. C. 305(a) PARTICULATE STRATEGY (DETAILED INVENTORY)

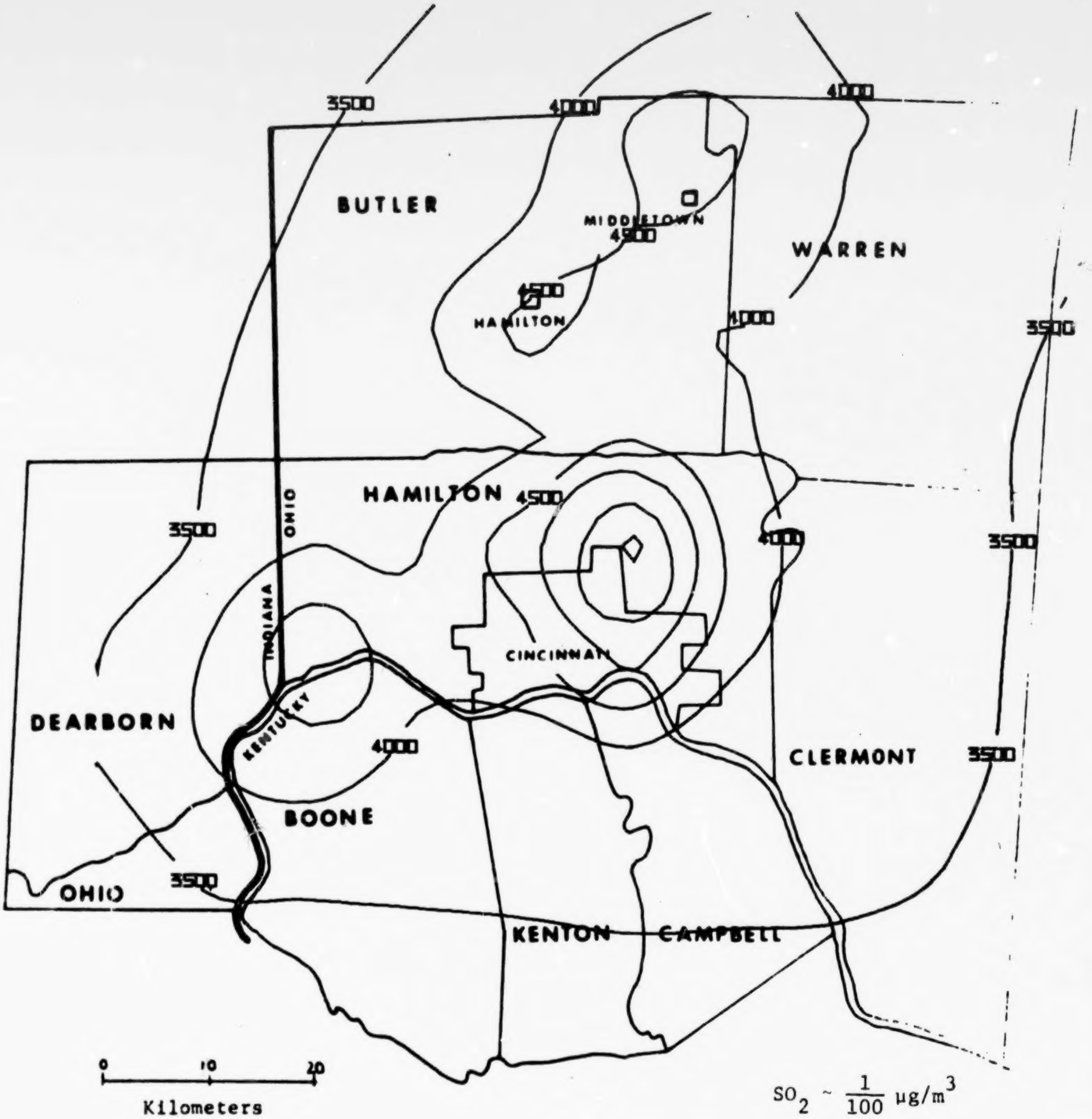
SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON **REMOVED**
o Steam/Electric	22	2	642	36.4	40.5	25.7	164.3
o Commercial/Institutional Boilers	120	12	276	23.8	13.4	7.1	45.3
o Industrial Boilers	9	0	0	.4	.8	.4	-
o Kraft Industry		0	0	0	0	0	-
o Iron and Steel	0	0	0	0	0	0	-
o Grey Iron	0	0	0	0	0	0	-
o **Non-Ferrous Metals**	0	0	0	0	0	0	-
o Sulfuric Acid	0	0	0	0	0	0	-
o Oil Refineries	0	0	0	0	0	0	-
o Asphalt Batching	7	1	10	9.7	1.3	7.2	11.0
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	1	0	0	.7	0	.7	-
o Fuel Combustion	151	16	918	61.6	54.8	33.2	88.5
o Industrial Process	8	1	10	10.4	1.3	7.9	11.0
o Solid Waste Disposal	21	6	140	13.5	3.9	3.8	46.3
o TOTAL	180	23	1,069	85.5	59.9	44.9	72.1

TABLE 3-8 EFFECTS OF REGULATIONS; WASHINGTON, D.C. 305(a)/2 SO_2 STRATEGY (DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON **REMOVED**
o Steam/Electric	22	22	15,245	492.2	164.5	146.2	120.7
o Commercial/Institutional Boilers	120	108	8,931	47.2	33.5	25.4	1,123.5
o Industrial Boilers	9	9	325	2.6	1.8	1.3	702.0
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	0	0	0	0	0	0	-
o Grey Iron	0	0	0	0	0	0	-
o Non-Ferrous Metals	0	0	0	0	0	0	-
o Sulfuric Acid	0	0	0	0	0	0	-
o Oil Refineries	0	0	0	0	0	0	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	0	0	0	0	0	0	-
o Fuel Combustion	151	139	24,502	542.0	199.8	172.9	181.9
o Industrial Process	0	0	0	0	0	0	-
o Solid Waste Disposal	0	0	0	0	0	0	-
o TOTAL	151	139	24,502	542.0	199.8	172.9	181.9

TABLE 3-9 EFFECTS OF REGULATIONS; WASHINGTON, D.C. 305(a)/2 PARTICULATE STRATEGY (DETAILED INVENTORY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON REMOVED
o Steam/Electric	21	13	2,026	36.4	21.8	13.5	242.4
o Commercial/Institutional Boilers	120	26	747	23.8	6.9	3.7	102.6
o Industrial Boilers	9	0	0	.4	.4	.4	-
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	0	0	0	0	0	0	-
o Grey Iron	0	0	0	0	0	0	-
o Non-Ferrous Metals	0	0	0	0	0	0	-
o Sulfuric Acid	0	0	0	0	0	0	-
o Oil Refineries	0	0	0	0	0	0	-
o Asphalt Batching	7	3	24	9.8	.6	7.2	24.5
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	1	0	0	.7	0	.7	-
o Fuel Combustion	150	39	2,773	60.6	29.0	17.6	176.8
o Industrial Process	8	3	24	10.6	.6	7.9	24.5
o Solid Waste Disposal	21	7	156	13.5	3.7	3.7	43.6
o TOTAL	179	49	2,953	84.7	33.4	29.3	145.9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4000
BUTLER
MIDDLETOWN
4500
WARREN
4500
HAMILTON
4000
3500
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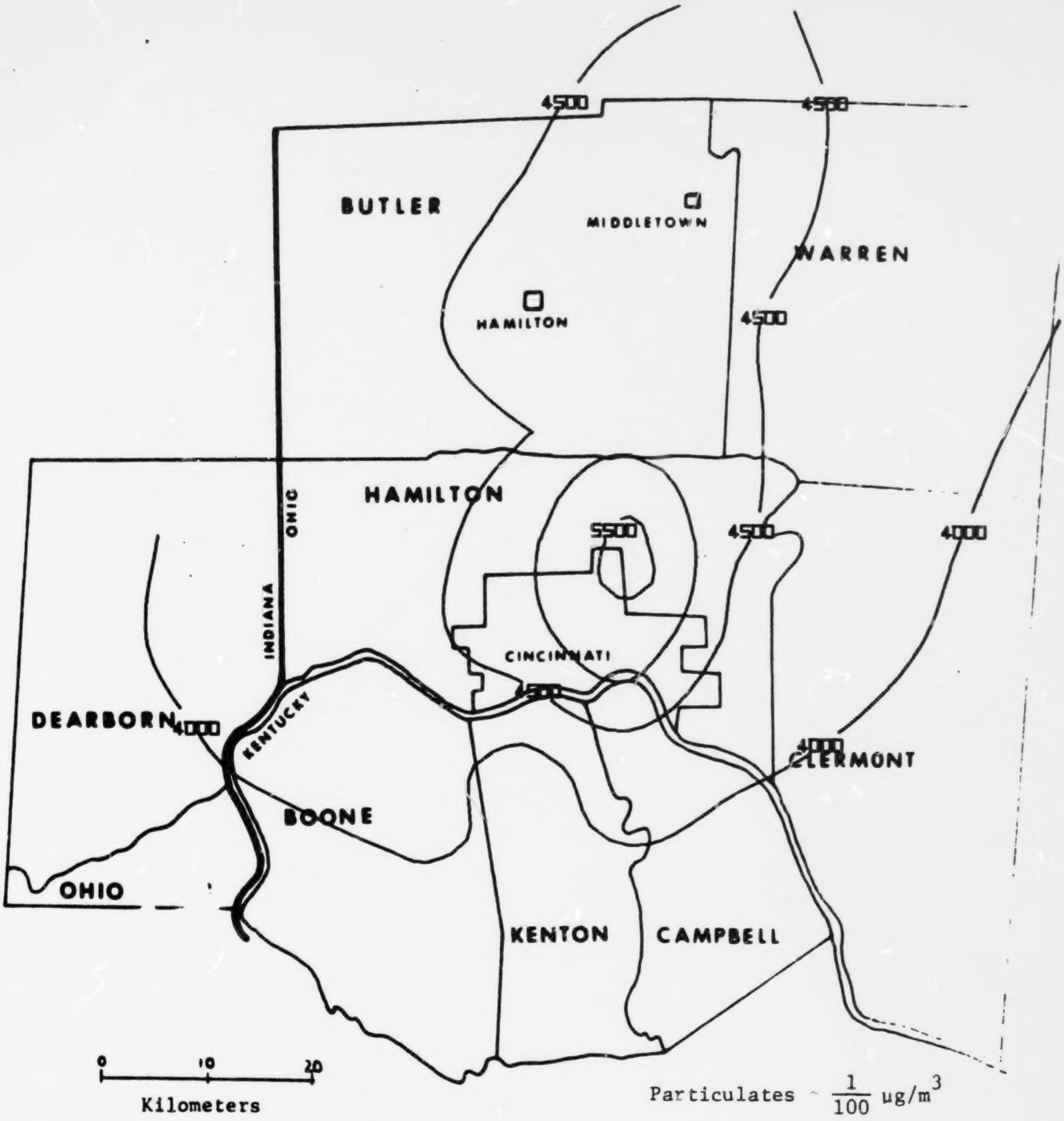
4500
OHIO
INDIANA
3500
4000
3500
CINCINNATI
KENTUCKY
DEARBORN
4000
CLERMONT
3500
BOONE
OHIO
3500
KENTON
CAMPBELL
0
10
20
Kilometers
SO2 ~ 1/100 µg/m3

Figure 3-1. Annual SO_2 Ground Level Concentrations, 305(a) Strategy, Cincinnati AQCR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4500
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HAMILTON
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INDIANA
5500
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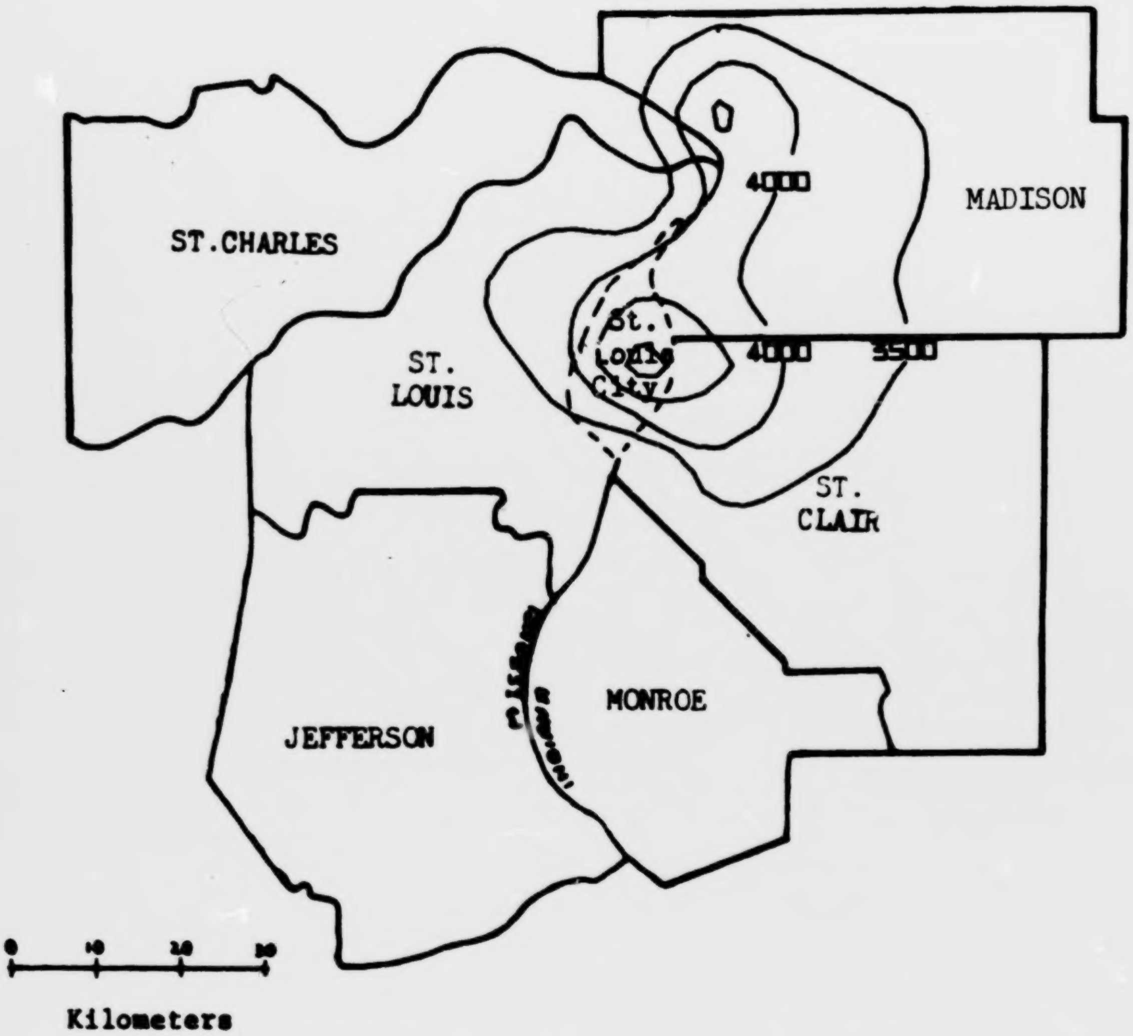
4000
CINCINNATI
4500
DEARBORN
4000
KENTUCKY
4000
CLERMONT
BOONE
OHIO
KENTON
CAMPBELL
0 10 20
Kilometers
Particulates ~ $\frac{1}{100}$ µg/m^3

Figure 3-2. Annual Particulate Ground Level Concentrations, 305(a) Strategy, Cincinnati AQCR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ST.
LOUIS
St.
Louis
City
0
4000
MADISON
4000
3500
ST.
CLAIR
MONROE
JEFFERSON
MISSISSIPPI RIVER
0
10
20
30
Kilometers

$SO_2 \sim \frac{1}{100}\ \mu g/m^3$

Figure 3-3. Annual SO_2 Ground Level Concentrations, 305(a) Strategy, St. Louis AQCR

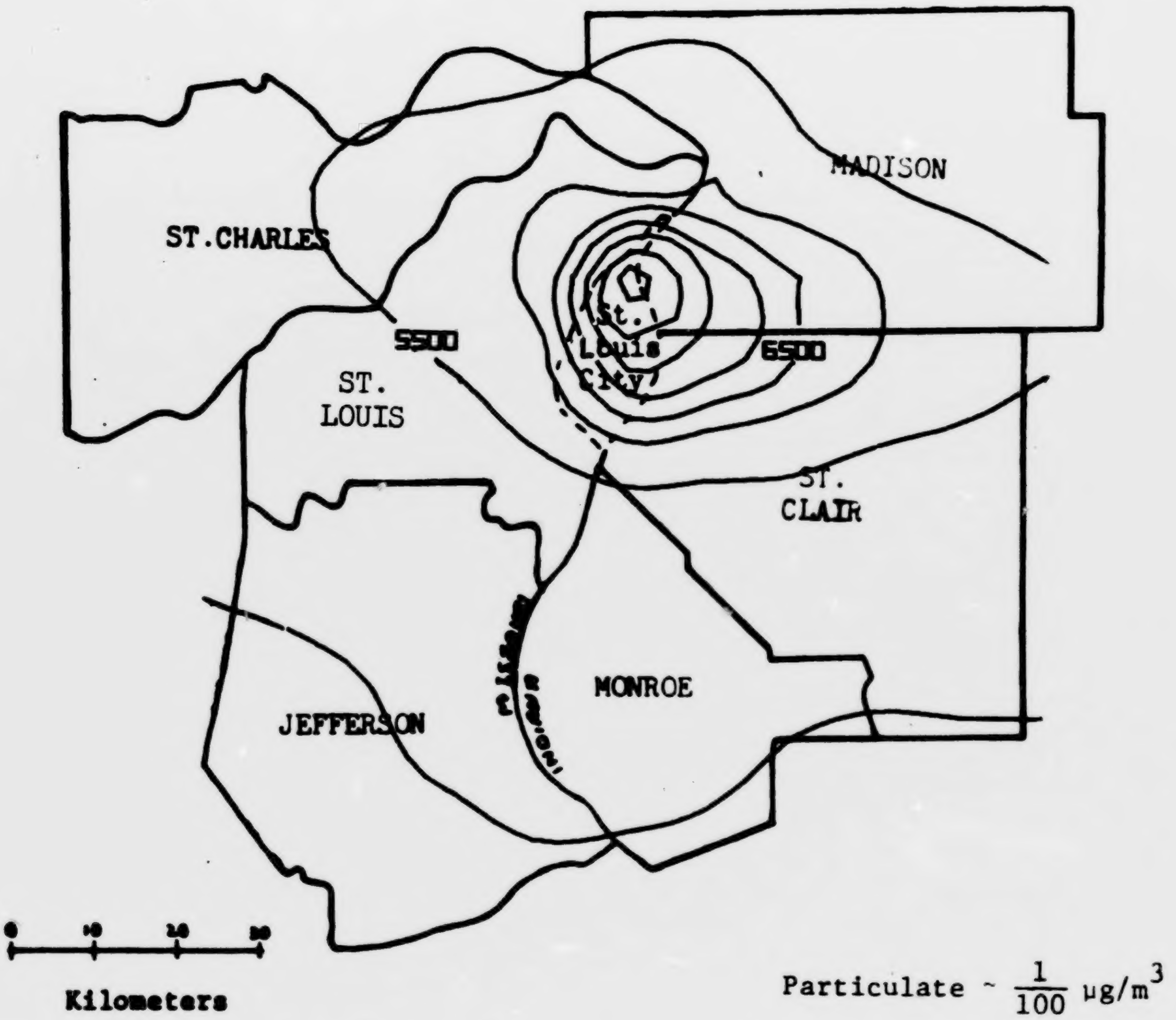

MADISON
ST.CHARLES
5500
St.
Louis
City
6500
ST.
LOUIS
ST.
CLAIR
Mississippi
Illinois
MONROE
JEFFERSON
0
10
20
30
Kilometers
Particulate ~ 1/100 μg/m3

Figure 3-4. Annual Particulate Ground Level Concentrations, 305(a) Strategy, St. Louis AQCR

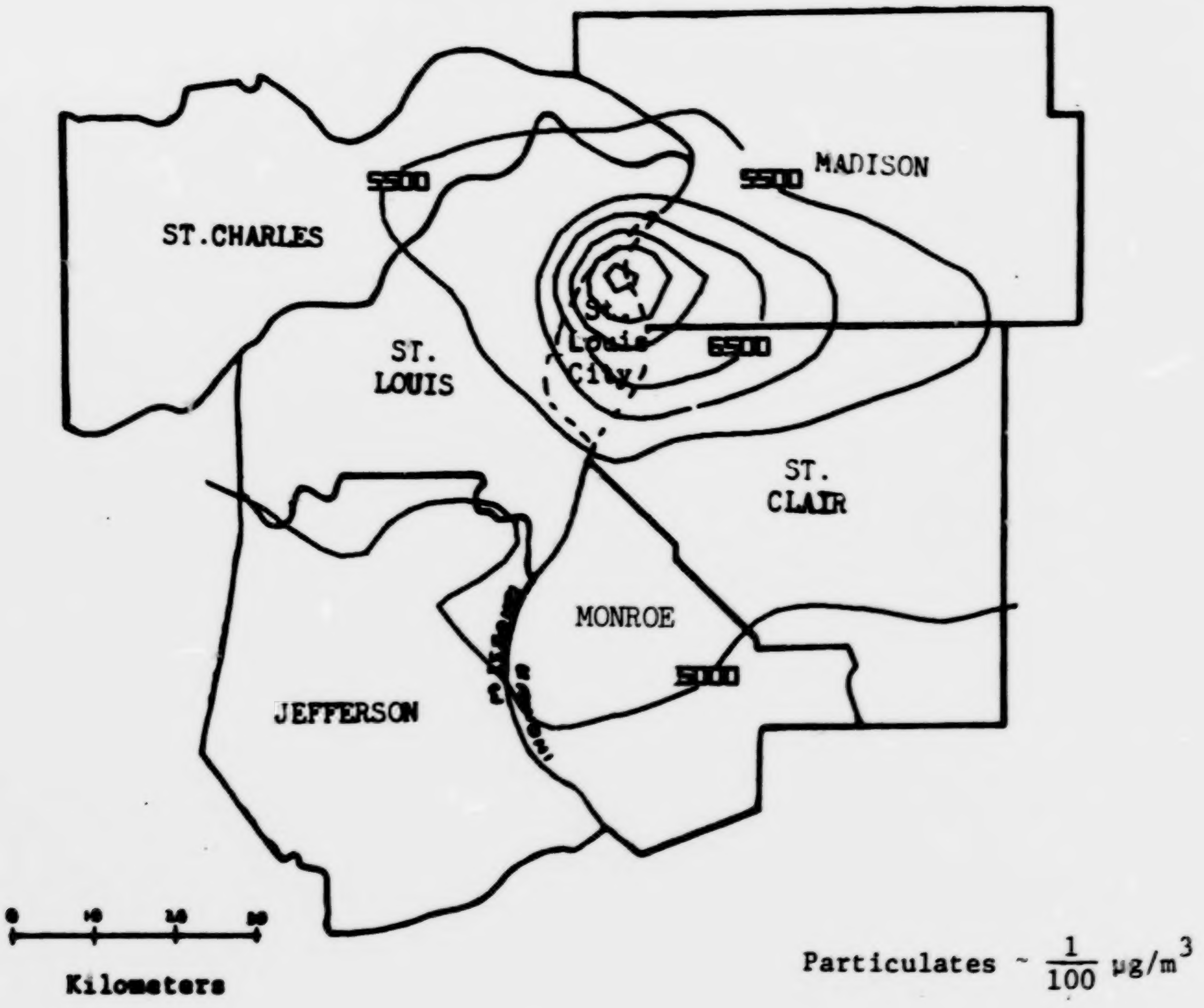
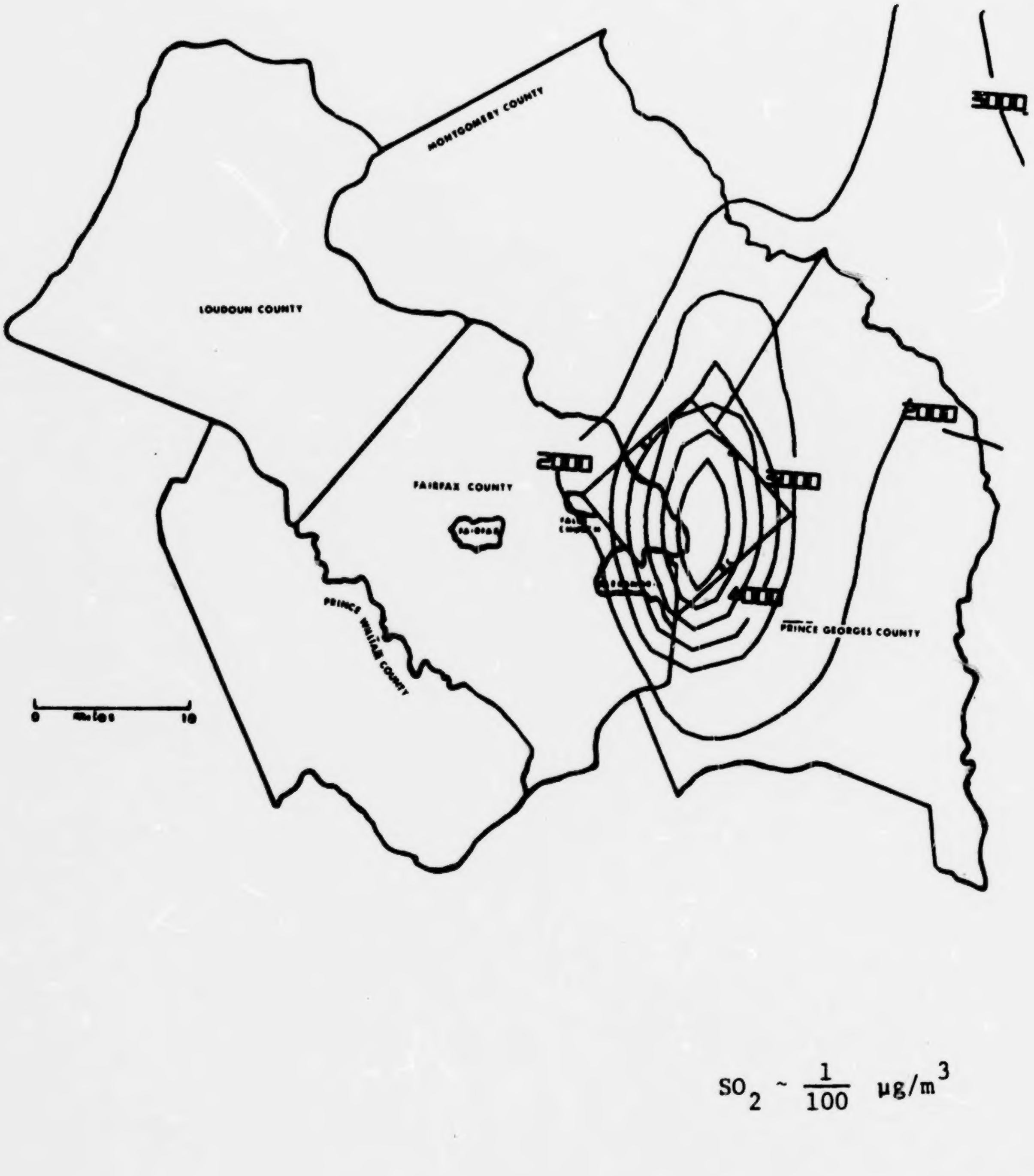
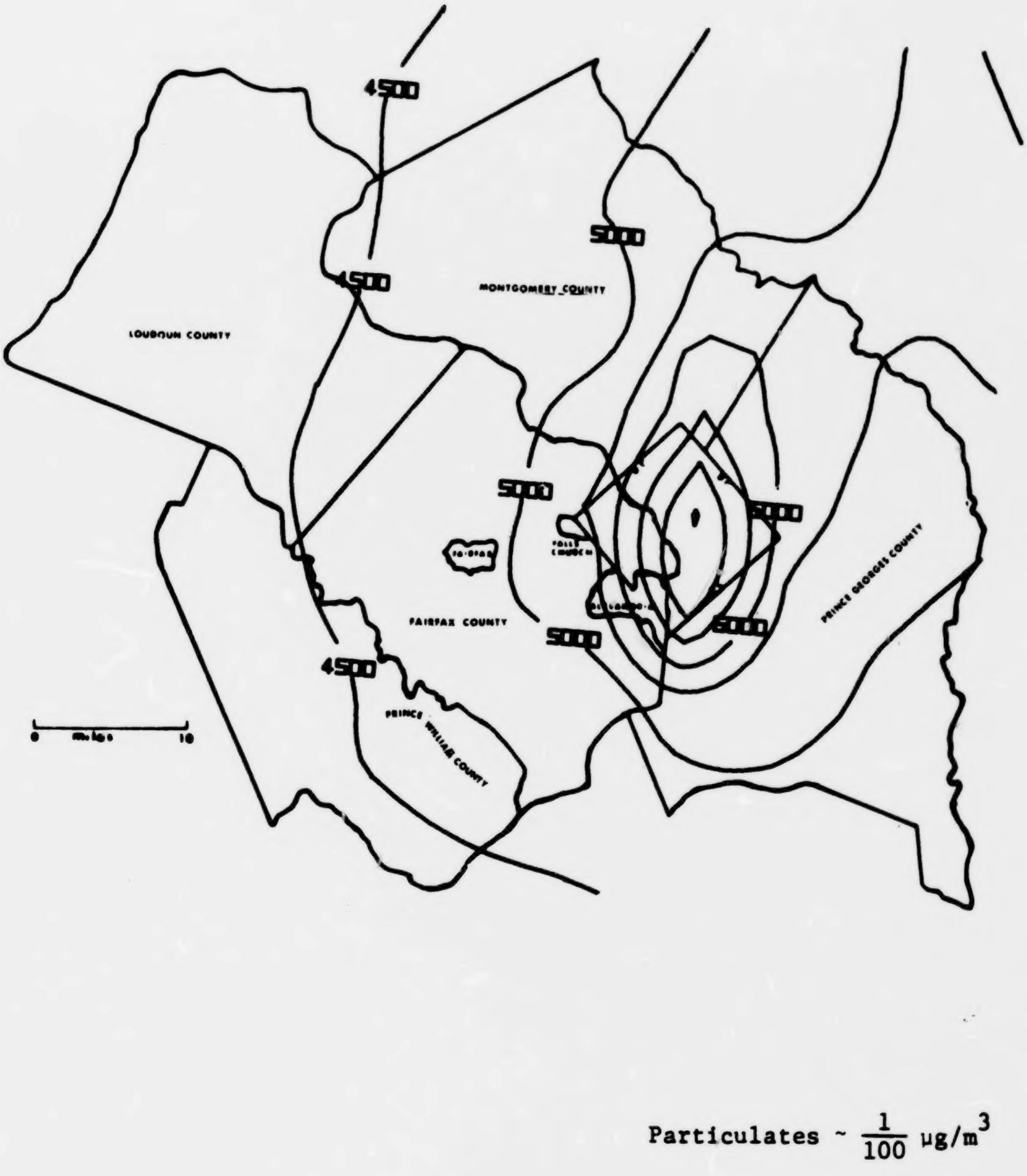

5500
5500
MADISON
ST.CHARLES
ST.
LOUIS
St.
Louis
City
6500
ST.
CLAIR
MONROE
5000
JEFFERSON
0
10
20
30
Kilometers
Particulates ~ $\frac{1}{100}$ µg/m^3

Figure 3-5. Annual Particulate Ground Level Concentrations, 305(a)/4 Strategy, St. Louis AQCR


MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
PRINCE WILLIAM COUNTY
PRINCE GEORGES COUNTY
FALLS CHURCH
3000
2000
2000
3000
4000
0 miles 10

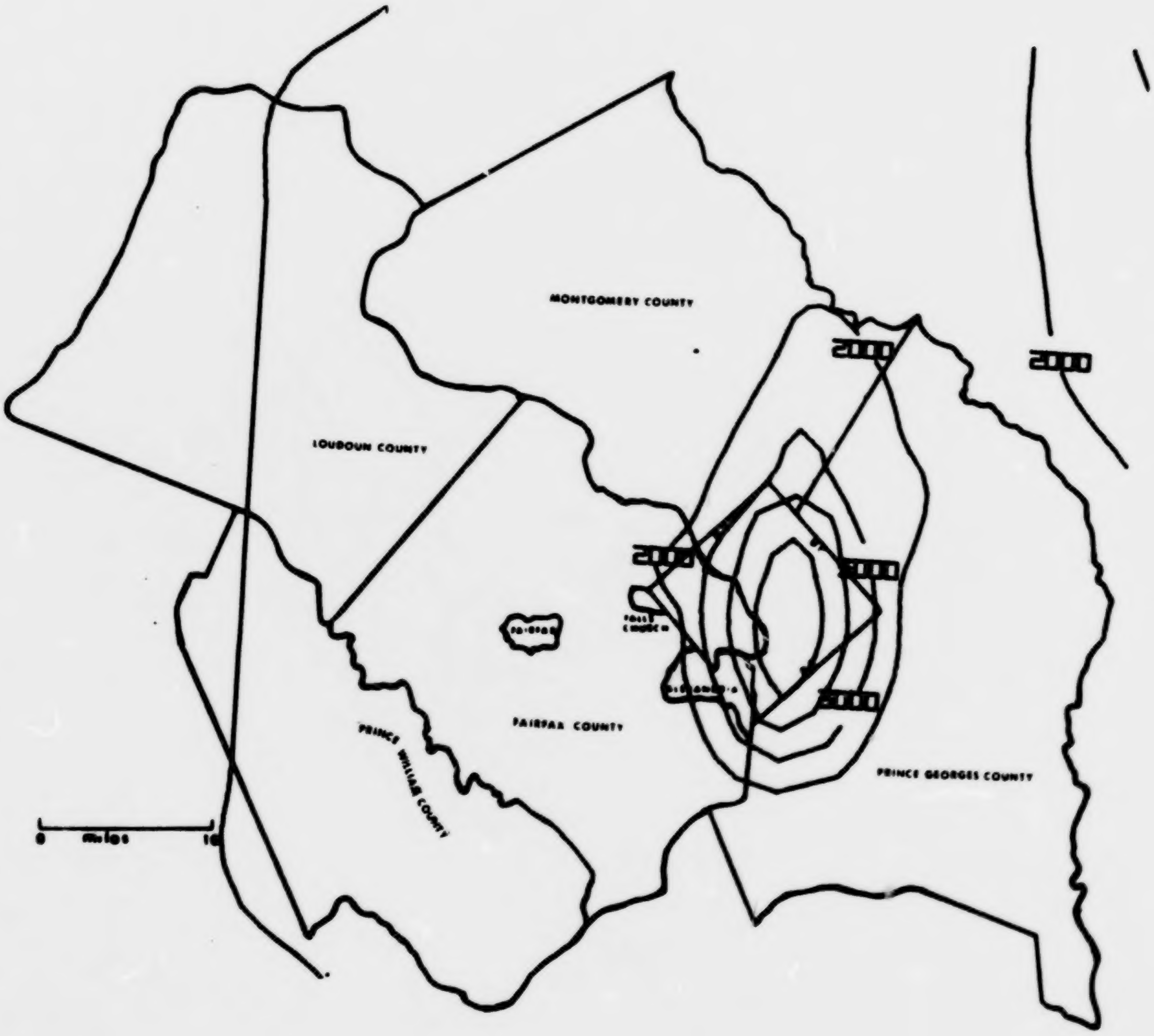
$SO_2 \sim \frac{1}{100}\ \mu g/m^3$

Figure 3-6. Annual SO_2 Ground Level Concentrations, 305(a) Strategy, Washington, D.C. AQCR


4500
5000
MONTGOMERY COUNTY
LOUDOUN COUNTY
4500
5000
FAIRFAX
FALLS CHURCH
5000
ALEXANDRIA
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
5000
5000
4500
PRINCE WILLIAM COUNTY
0 miles 10

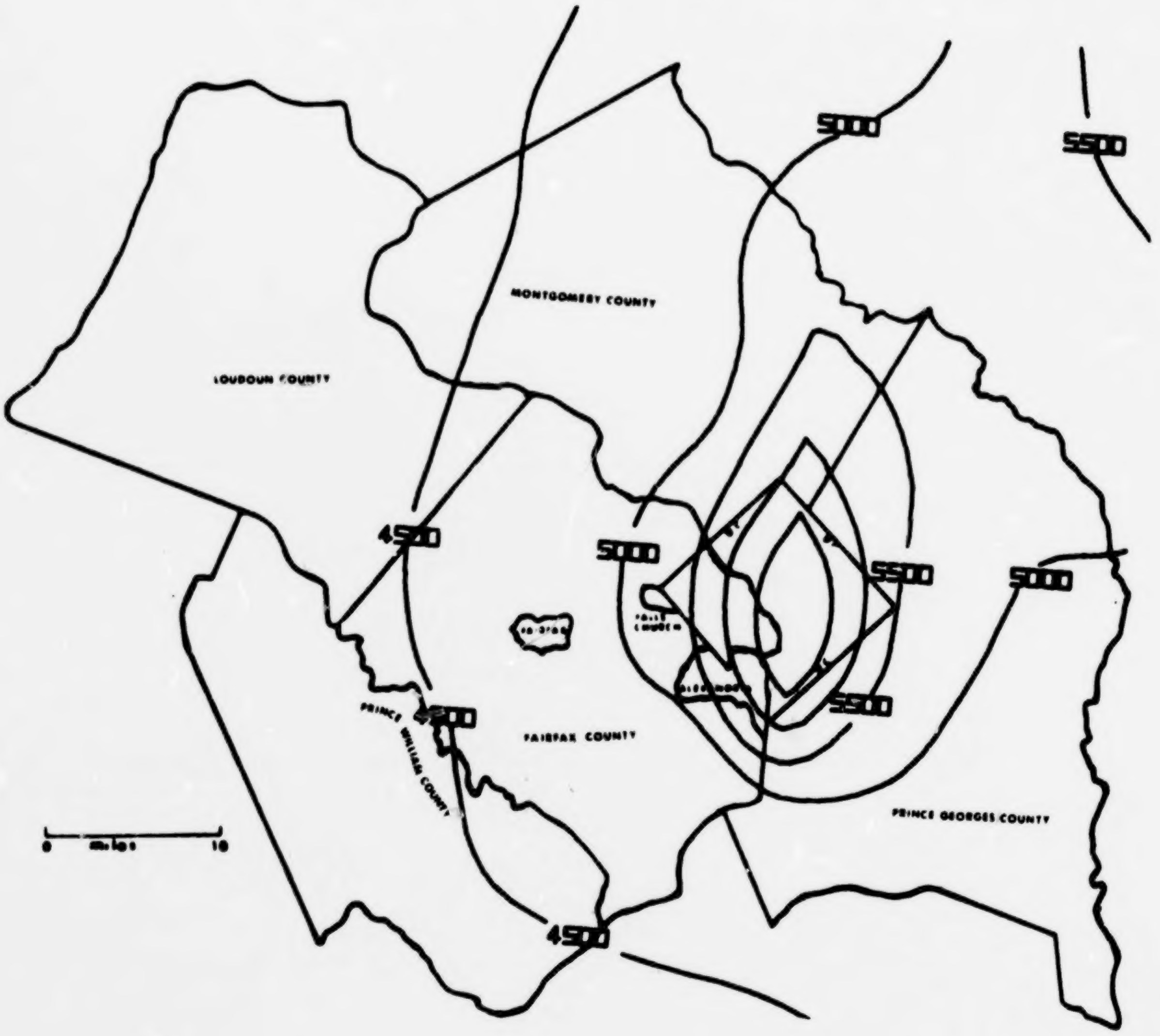
Particulates ~ $\frac{1}{100}$ $\mu g/m^3$

Figure 3-7. Annual Particulate Ground Level Concentrations, 305(a) Strategy, Washington, D.C. AQCR


MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX
FALLS CHURCH
ALEXANDRIA
FAIRFAX COUNTY
PRINCE WILLIAM COUNTY
PRINCE GEORGES COUNTY
2000
2000
2000
2000
3000
0 miles 10

$SO_2 \sim \frac{1}{100}\ \mu g/m^3$

Figure 3-8. Annual SO_2 Ground Level Concentrations, 305(a)/2 Strategy, Washington, D.C. AQCR


5000
5500
MONTGOMERY COUNTY
LOUDOUN COUNTY
4500
5000
5500
5000
FALLS CHURCH
5500
PRINCE WILLIAM COUNTY
4500
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
0 miles 10
4500

Particulates ~ $\frac{1}{100}$ $\mu g/m^3$

Figure 3-9. Annual Particulate Ground Level Concentrations, 305(a)/2 Strategy, Washington, D.C. AQCR

- The particulate standards become stricter as plant size increases, so powerplant emission reductions are the greatest.

The desired 65 $\mu g/m^3$ air quality is achieved for both SO_2 and particulates using the base 305(a) emission standards (Figures 3-1 and 3-2).

3.1.2 St. Louis AQCR

The annual cost of applying the 305(a) emission standards to the point sources of the St. Louis AQCR is $20,187,000 for SO_2 control and $12,693,000 for particulate control. These costs are significantly greater than those incurred in Washington, D.C. and Cincinnati. In terms of cost effectiveness, the three regions compare as follows:

	Cost Effectiveness, $/Ton Removed	
Region	SO_2	Particulate
Cincinnati	16.00	26.60
St. Louis	43.53	93.68
Washington, D.C.	18.60	76.89

One reason for the very high SO_2 costs is that according to the available data, low sulfur fuel is quite expensive in St. Louis. For instance, the price that powerplants pay for 1.25% sulfur content coal is $9.20 per ton in St. Louis, and only $6.25 per ton in Cincinnati. In addition, the variation of price with sulfur level is high, so that a fuel switch from 2.3% sulfur content coal to 1.25% sulfur content coal costs $3.20 per ton additional for powerplants. A switch to 1% sulfur content coal costs $6.40 per ton, which is extremely high.

As in Cincinnati, powerplants produce a major share of the total emissions in the region both before and after control. However, the larger industrial base in St. Louis contributes to a more balanced emission inventory. Powerplants account for 63 percent of the SO_2 and 42 percent of the particulate point source emissions prior to implementation of the 305(a) strategy, and 62 and 25 percent, respectively, of the post-strategy emissions.

According to the isopleths in Figures 3-3 and 3-4, the 305(a) SO_2 strategy is successful in achieving a 65 $\mu g/m^3$ level throughout the region, whereas the particulate strategy is notably unsuccessful. Particulate strategies of twice and four times the strictness of the 305(a) standards were unsuccessfully tested; the results of the latter are illustrated in Table 3-5 and Figure 3-5. Unfortunately, the isopleths in Figures 3-4 an 3-5 include the effects of an error in the source file discovered after the completion of the runs. A coking plant had been assigned a particulate emission of 30.8 tons/day, whereas its actual emission is 3.08 tons/day. Since the original 305(a) particulate standards achieve a 77 percent reduction in emissions, they should probably be considered as satisfactory for the major point sources of the region.

3.1.3 Washington, D.C. AQCR

The annual cost of implementing the 305(a) emission control strategy in the Washington, D.C. AQCR is \$1,754,000 for SO_2 and \$1,069,000 for particulate control. A striking feature of the Washington control cost and emissions "picture" is the lack of industrial emissions. There are no major industrial SO_2 emission sources in the AQCR, and only a few particulate sources. Powerplants supply 91 percent of the SO_2 and 43 percent of the existing point source emissions, and 83 and 57 percent, respectively, of the post-control emissions.

Despite the lack of industrial polluters, the 305(a) standards do not achieve the desired air quality in the AQCR. The heavy concentration of small residential emission sources and the area's powerplants and incinerators require stricter standards. According to Figures 3-10 and 3-11, the application of standards twice as strict as the 305(a) base standards cause a notable improvement in air quality, and it may be expected that a slightly stricter set of standards will indeed achieve the desired level. The additional annual cost to the region of the 305(a)/2 strategies is \$22,748,000 for SO_2 and \$1,813,000 for particulate control, above those predicted for the 305(a) strategies.

3.2 COST OF SIMULTANEOUS PARTICULATE AND SO_2 CONTROL

The costs presented in Tables 3-1 through 3-9 represent the costs of applying a one-pollutant control program independently of any other programs. The interaction between pollutant strategies is ignored.

It must be recognized that this separation of pollutants does not apply in the real world. Many control devices are effective in controlling more than one pollutant; when these devices are utilized, a link between separate pollutant control strategies is established and should not be ignored. The "cost" of instituting simultaneous particulate and SO_2 strategies cannot be considered as merely the sum of the costs of each taken separately. There is considerable "double-counting" and other errors inherent in such a simple calculation. For instance, a fuel switch to natural gas can be used for both particulate and SO_2 control. When this switch appears for a single source in both a particulate strategy run and an SO_2 run, the analyst must subtract the cost of a single switch from the combined total to avoid counting this cost twice. The analyst must also reconcile the two strategies when the following situation occurs:

For a single source:

- Particulate strategy chooses device X1 at cost Y1.
- SO_2 strategy chooses device X2 at cost Y2.
- A third device X3 exists which will satisfy both the particulate and the SO_2 standards, and whose cost Y3 is less than the combined total (Y1 + Y2) but greater than either Y1 or Y2.

In a least-cost solution, device X3 would be the proper choice. In a proper summation procedure, Y3 would be substituted for (Y1 + Y2).

Table 3-10 presents the combined costs of SO_2 and particulate runs for the three AQCR's. The summation procedure is as described above. It is interesting to calculate the difference between the reconciled total cost and the simple sum of the two costs. The simple sum of the costs in the Cincinnati AQCR yields a total cost of 7.307 million dollars per year to control the major sources in the region. Reconciling the two strategies yields a reduction of 675 thousand dollars, about a 9 percent change. While a change of this magnitude is probably well within a reasonable margin of error for this type of calculation, it can be expected that a significantly larger difference will appear under altered circumstances, for instance, where widespread switching from coal to low sulfur oil or natural gas is used for both SO_2 and particulate control.

TABLE 3-10. COST OF CONTROL FOR THREE CITIES, 305(a) SO_2/PARTICULATE STRATEGY

SOURCE CATEGORY	COST , $/YEAR		
	St. Louis	Cincinnati	Washington, D.C.
• Steam/Electric	14,173,363	4,717,571	2,373,590
• Commercial/ Institutional Boilers	314,518	37,325	344,225
• Industrial Boilers	6,105,726	824,732	0
• Kraft	0	0	0
• Iron and Steel	554,654	670,805	0
• Grey Iron	27,248	0	0
• Non-Ferrous Metals	519,500	0	0
• Sulfuric Acid	562,578	140,852	0
• Oil Refineries	945,928	0	0
• Asphalt Batching	0	13,273	9,923
• Cement	152,643	0	0
• Grain	4,469,265	0	0
• Varnish	0	0	0
• Other Process Sources	1,947,441	13,273	0
• Solid Waste Disposal	85,921	231,000	164,000

3.3 RESULTS OF POLLUTANT CONTROL STRATEGIES - DEVICE DEMAND

Tables 3-11 through 3-13 show the control device demands and costs generated by the 305(a) emission standards. The selection of these devices is based on the assumed policy of selecting the least expensive device which will satisfy the required allowable emissions specified by the emission standards. The "total" columns compensate for the double-counting described in Section 3.2.

3.3.1 Cincinnati AQCR

The bulk of the air pollution control required by the 305(a) standards in Cincinnati is handled by Wet Limestone Injection and Fuel Switching, for SO_2 control, and by Fabric Filters and Electrostatic Precipitators for particulate control. The fuel switching to .8% sulfur coal has some beneficial effect on particulate emissions because the coal has a lower ash content than the high sulfur coal being used. The nearly 3 million dollar cost of the switching represents 1,370,000 tons of low sulfur coal, of which 1,250,000 tons are consumed by powerplants.

Other significant features are:

- The Wet Limestone Injection process is represented by only one device, but it removes 160 tons of SO_2 daily from the emissions of one of the AQCR's major powerplants.
- Centrifugal collectors (cyclones), while not accounting for a substantial portion of the costs, are nevertheless represented by 23 devices.

3.3.2 St. Louis AQCR

The control device demands generated in the St. Louis AQCR by the 305(a) standards are similar to those in Cincinnati but are of a higher magnitude. Significant features are:

- The Wet Limestone Injection process is represented by 8 large devices costing a total of nearly 11 million dollars.
- Switching to low sulfur oil and natural gas is extremely substantial, representing an annual

TABLE 3-11 CINCINNATI DEVICE DEMAND AND COST, 305(a) STRATEGY (DETAILED INVENTORY)

DEVICE NAME	SO_2		PARTICULATES		"TOTAL"(reconciled)	
	NO.SOURCES	COST,$/YR.	NO.SOURCES	COST	NO.SOURCES	COST
1. Wet Scrubber - Hi Eff	0	0	1	67,200	1	67,200
3. Wet Scrubber - Lo Eff	0	0	7	201,000	7	201,000
7. Cyclone - Hi Eff	0	0	12	136,800	12	136,800
8. Cyclone - Med Eff	0	0	11	93,500	11	93,500
10. Elect. Precipitator - Hi Eff	0	0	5	329,400	5	329,400
11. Elect. Precipitator - Med. Eff	0	0	2	143,900	5	143,900
12. Elect. Precipitator - Lo Eff	0	0	10	700,500	8	368,500
13. Gas Scrubber	3	126,100	0	0	3	126,100
15. Mist Eliminator - Lo Vel	0	0	1	14,700	1	14,700
16. Fabric Filter - Hi Temp	0	0	10	853,400	10	853,400
17. Fabric Filter - Med Temp	0	0	1	4,900	1	4,900
18. Fabric Filter - Lo Temp	0	0	3	672,200	3	672,200
28. Fuel Subst., .8% S. Coal	26	2,630,000	14	343,200	31	2,633,000
29. Fuel Subst., .3% S. Coal	0	0	4	10,300	10	10,300
30. Fuel Subst., 1.25% S. Oil	0	0	1	16,600	0	0
42. Wet Limestone Injection	1	1,212,900	1	1,212,900	1	1,212,900

TABLE 3-12. ST. LOUIS DEVICE DEMAND AND COST, 305(a) STRATEGY (DETAILED INVENTORY)

DEVICE NAME	SO_2		PARTICULATES		"TOTAL"(reconciled)	
	NO.SOURCES	COST, $/YR.	NO.SOURCES	COST	NO.SOURCES	COST
2. Wet Scrubber - Med Eff	0	0	2	85,900	2	85,900
3. Wet Scrubber - Lo Eff	0	0	3	146,000	3	146,000
7. Cyclone - Hi Eff	0	0	5	126,900	1	2,800
8. Cyclone - Med Eff	0	0	6	391,700	4	357,800
10. Elect. Precipitator - Hi Eff	0	0	10	2,176,500	7	1,273,800
11. Elect. Precipitator - Med Eff	0	0	6	1,392,900	1	456,700
12. Elect. Precipitator - Lo Eff	0	0	9	563,700	0	0
13. Gas Scrubber	4	270,100	0	0	4	270,100
14. Mist Eliminator - Hi Velocity	0	0	1	19,000	1	19,000
15. Mist Eliminator - Lo Velocity	0	0	4	273,400	4	273,400
16. Fabric Filter - Hi Temp	0	0	21	4,763,200]	15	4,410,400
18. Fabric Filter - Lo Temp	0	0	8	489,200	8	489,200
20. Catalytic Afterburner	0	0	1	1,228,200	1	1,228,200
32. Fuel Subst., 1% Sulfur Oil	12	6,967,800	1	174,700	12	6,967,800
33. Fuel Subst., Natural Gas	21	1,395,000	7	442,600	23	1,519,000
42. Wet Limestone Injection	8	10,897,900	0	0	8	10,897,900
43. Sulfuric Acid Plant Contact Proc.	1	*			1	*

* Model predicts a profit from sale of marketable acid.

TABLE 3-13. WASHINGTON, D.C. DEVICE DEMAND AND COST, 305(a) STRATEGY (DETAILED INVENTORY)

DEVICE NAME	SO_2		PARTICULATES		TOTAL (Reconciled)	
	No.Sources	Cost,$/Yr.	No.Sources	Cost	No.Sources	Cost
2. Wet Scrubber - Med. Eff.	0	0	2	52,800	2	52,800
3. Wet Scrubber - Lo Eff.	0	0	4	87,300	4	87,300
9. Cyclone - Lo Eff.	0	0	1	8,200	1	8,200
12. Elect. Precipitator - Lo Eff.	0	0	5	666,700	5	666,700
16. Fabric Filter - Hi Temp	0	0	8	194,900	8	194,900
18. Fabric Filter - Lo Temp	0	0	1	9,900	1	9,900
28. Fuel Subst. .7% S Coal	8	1,732,000	0	0	8	1,732,000
30. Fuel Subst. 1.0% S Oil	1	22,200	1	26,200	2	48,500

outlay of over 8 million dollars. The requirement for 1% sulfur content oil in the AQCR exceeds 4.6 million barrels (over 190 million gallons) annually.

- Fabric filters are used to control very large feed and grain operations at a cost exceeding 4 million dollars.
- An interesting feature is the use of a sulfuric acid plant (contact process) which actually shows a net profit through the sale of the collected and transformed SO_2. The controlled plant is a lead smelter.

3.3.3 Washington, D.C. AQCR

The major control devices utilized in the Washington, D.C. AQCR are electrostatic precipitators for particulate and fuel switching to low sulfur coal for SO_2 control. A demand for 2,775,000 tons of .7% sulfur content coal, at an additional cost of $1,732,000 is generated by the 305(a) SO_2 standards.

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4.0 AGGREGATION APPROACH

The Aggregation Approach to the prediction of national pollution control costs and control device demands involves the processing of a large number of regions through the IPP model, generating estimates of regional and industry group control costs and device demand, and simply adding (aggregating) the results to provide a "national-level" estimate. The approach is attractive because Rapid Survey emission inventories already exist for upwards of 40 regions, and thus an expensive data collection effort is avoided if these surveys can provide a usable and accurate "emission source file" for use in the model.

The Cincinnati and St. Louis Rapid Surveys were chosen as test cases to evaluate the approach, primarily because of the availability of detailed emission inventories for these regions which can be used for comparative purposes. These detailed inventories represent a substantial step upwards in the care and effort with which they were assembled. They normally require a man-year of labor or more, whereas a Rapid Survey inventory can be completed in three to six man-weeks. It should be noted, however, that the key difference between the Rapid Survey, in its ideal form, and the detailed inventory is the number of variables collected and the care with which they are obtained; the inaccuracies in the Rapid Surveys which are due solely to the need to estimate rather than measure--for instance, with respect to annual emission rates--are to a certain extent present in the detailed inventory also. The detailed inventory provides a good but far from perfect standard against which to measure the Rapid Survey.

Since the variables collected by the Rapid Surveys are insufficient for running the IPP model, the survey data must be expanded using industry-wide or region-wide averages, and empirical or theoretical relationships between various emission/control variables. The expanded inventories are then utilized in the model to measure the effects of a pollution control strategy consisting of the emission standards of the 1970 Cost of Clean Air (305(a)) Report to Congress; the results are directly comparable to detailed inventory IPP results based on the same strategy.

The utility of the Aggregation Approach may be judged on the basis of the answers to the following questions:

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- Does the (built-up) Rapid Survey emission inventory provide a reasonably accurate measure of control device demand and cost?
- Is the effort to "build-up" these inventories and run them on IPP moderate enough to justify repeating the process for 40 additional regions?
- To what extent do the 40 or so regions represent the nation in terms of population, industrial output, electric power generated, etc.?

4.1 RAPID INVENTORIES

The Rapid Survey technique of compiling community air pollution inventories is centered about estimating air pollution emissions without incurring the expense of direct stack sampling and detailed and extensive plant surveys. The technique is designed to produce reasonably accurate estimates of:

1. The annual total and seasonal weight of emissions of selected pollutants.
2. The relative importance of various fuels and types of sources in producing the emissions.
3. The relative amounts of pollutants emitted in various geographic sub-areas of the community (Reference 3). The technique is not meant as a substitute for detailed surveys but instead is designed to "provide reasonable information for making intelligent decisions in air conservation programs in many communities at an earlier time than might otherwise be possible"(Reference 3). Thus, it is to be expected that the accuracy and level of detail of the Rapid Surveys will be significantly lower than that of the Detailed inventories.

The pollution "sources" in a community include both the large industrial and commercial plants and also such small but important (in the aggregate) sources as automobiles, backyard burning, apartment house incinerators, etc. As the first step in the Rapid Survey technique, the sources in the community are divided into two categories: point sources, which are those sources which satisfy some predetermined minimum size measure (a minimum emission in tons/year, minimum plant capacity, or some other measure), and area sources, which include all other sources in the community.

Point sources are handled individually in the survey; one plant equals one pollution source. In an average sized community, a Rapid Survey will include 10 to 50 point sources, although this number may expand considerably for a large city. The point source inventory normally includes:

- all steam-electric power plants
- municipal incinerators
- large manufacturing plants (both as fuel combustion sources and process sources)
- large institutions such as hospitals

Point sources are individually surveyed for the following information

- Name
- Number of employees
- Industrial Classification (SIC code)
- Location
- Fuel use, by fuel (if plant is a fuel combustion source)
    - Total
    - Process needs
    - Space heating
    - Fuel sulfur and ash content
- Equipment, by fuel--for each boiler
    - Equipment type
    - Rated capacity
    - Fuel burned
    - Control equipment type
    - Control efficiency

If the plant is a "process source," i.e., if the pollution is directly caused by a manufacturing process rather than by combustion of fuel in an indirect heat exchanger, the survey would be altered to collect data on production rather than fuel use.

Given the information listed above, a reasonably accurate estimate of air pollution emission may be made by making use of "emission factors" which relate emission to either fuel use (combustion sources) or production (process sources). For instance, from Reference 3, sulfur dioxide emissions from the burning of 1 ton of coal are approximately equal to 38 pounds times the sulfur content (in percent by weight) of the coal. Particulate (ash) emission from the burning of coal may be measured in a similar manner, although the emission factors are here strongly dependent on the type of boiler used.

An area source represents an aggregation of many small sources which is treated as a single source. The magnitude of emissions from each component of an area source (if the source is composed of more than one type of emitter) is calculated by various methods described in detail in Reference 3. For instance, emissions from residential areas (space heating) may be estimated by the use of an empirical formula using degree days, number of households using a fuel, and an average fuel requirement per household per degree day. Data on degree days is available from the weather service, while the number of households is available from local fuel distributors.

4.2 CONSTRUCTION OF THE EMISSION SOURCE FILE

Table 4-1 presents the point source variables used by the IPP model. As noted, several of them are unnecessary for operation of the model, and several others may be assumed to be equal to region-wide or industry-wide averages, probably without significant loss of accuracy. Since at this time no detailed study has been conducted of the precise role that each variable plays in determining the accuracy of the model results, the process of "building up" a Rapid Inventory to the point where it may be used in IPP will consist of calculating as many of the variables in Table 4-1 as possible.

It should be recognized at the onset that the nature of the goals of this task...to gauge the usefulness of the Rapid Survey Technique in implementation modeling, and to judge whether the Aggregation Approach should be used to estimate national control device demand and costs...requires that each technique selected to calculate a variable should, ideally, be

Table 4-1. IMPLEMENTATION PLANNING PROGRAM POINT SOURCE VARIABLES

Source Variable	Comments
Source ID	1
X Location	1
Y Location	1
Political Jurisdiction	2
Ownership	2
Source Type*	1
Stack Height (M)	3
Stack Diameter (M)	5
Exit Velocity (M/Sec)	5
Exit Temperature (°K)	3
Existing Control Device	4
Existing SO_2 Control Efficiency	4
Existing Particulate Control Efficiency	4
Exhaust Gas Volume, ACFM, from stack	1
Rated Capacity of Plant (BTU/hr)	1
Operating Time (Hr/Yr)	3
Annual Shifts (Shifts/Day)	3
Original Coal Cost ($/Ton)	3
Original Oil Cost ($/Gallon)	3
Original Gas Cost ($/Ft.^{3})	3
Original Coal Heat Content (BTU/Ton)	3
Original Oil Heat Content (BTU/Gal)	3
Original Gas Heat Content (BTU/Ft.^{3})	3
Electricity Cost ($/kwh)	3
Control Device Fuel Cost ($/Ft.^{3})	3
Disposal Factor, SO_2 ($/Ton)**	3
Disposal Factor Particulates ($/Ton)	3
Liquid Cost ($/Gal)	3
Manufacturing Process Unit	1
Process Rate (Process Units/Day)***	1
Coal Use (Tons/Day)	1
Oil Use (Gal/Day)	1
Gas Use (Ft.^{3}/Day)	1

Table 4-1. IMPLEMENTATION PLANNING PROGRAM POINT SOURCE VARIABLES (Continued)

Source Variable	Comments
Original Coal Sulfur Content (%)	6
Original Oil Sulfur Content(%)	6
Emission Rate SO_2 (Tons/Day)	1
Emission Rate Particulates (Ton/Day)	1

---

*Fuel Combustion Source, Process Source, or Solid Waste Disposal Source.

**Disposal Factor is the price that the plant can get for the material captured by the control device. For instance, certain SO_2 control devices produce marketable sulfuric acid.

***The Process Rate is defined as the rate of raw material consumed by the plant in a manufacturing process.

Comments:

1. These variables are absolutely essential for operation of the model and must be calculated on an individual basis, i.e., industry-wide or region-wide averages are insufficient.
2. These variables are not strictly needed for a region-wide analysis.
3. These variables are desirable but may be estimated using either region-wide or industry-wide averages, or else estimated as a function of SIC code.
4. These variables fit into comment 3, except that they assume much greater importance when emission rates have been calculated, using emission factors, rather than measured.
5. These variables are desirable but may be left out. An error is then introduced into the air quality calculations, however.
6. These variables are extremely desirable, but are often unavailable and must be assumed to be equal to region-wide averages.

a "best" technique in terms of both accuracy and ease of calculation. Of course, due to the limits of time, this demand is not always realized.

The variables collected in the "ideal" Rapid Survey are described in Section 4.1. The surveys investigated did not follow the precise format outlined in Reference 3, because of a lack of manpower resources and a stress on diffusion modeling, which does not require precise boiler-by-boiler information. As a result, some variables were entirely absent, and others were present in only a haphazard fashion (the St. Louis and Cincinnati Rapid Surveys were of course examined in great detail; however, several others, including those of Denver and Seattle, were also examined.)

In general, the following variables were available:

- Location, X and Y coordinates
- Source type
- Manufacturing process (source I.D.) but often in an overly general way, i.e., Chemical Plant, Rubber Plant, etc.
- Fuel use, if a fuel combustion source
- Production or process rate, if a process source (occasionally missing in Cincinnati Survey)
- SO_2 and particulate emission rates (obviously calculated from fuel rates or production figures)

Variables which are occasionally available include:

- Control device and/or efficiency
- Operating days per year
- Fuel sulfur levels
- Equipment types, i.e., spreader stoker, pulverized wet bottom, etc.

The following sections describe the process of estimating the missing variables.

4.2.1 Exhaust Gas Volume

Exhaust gas volume is a key variable in determining the cost of control devices. It is calculated for process sources by utilizing "gas volume factors" which relate gas volume to other key plant variables. Table 4-2 lists some key gas volume factors collected by the Research Triangle Institute (Reference 4). Note that many industries are not represented. Gas volumes for these industries were filled in, where possible, from the available detailed file. It is possible that the missing gas volume factors could be obtained with additional systems studies of the industries involved.

Exhaust gas volume for fuel combustion sources can be calculated by the derivation of factors similar to those in Table 4-2. The HEW document Atmospheric Emissions from Coal Combustion (Reference 5) contains a chart (reproduced as Figure 4-1) which allows the calculation of gas volume in ambient cubic feet per minute (acfm) given the fuel type, percent of excess air in the burning process, BTU content of the fuel and gas temperature.

As a sample calculation, assume:

- Fuel is LOW VOLATILE BITUMINOUS COAL
- Coal heat content $\approx 26 \times 10^6$ BTU/ton
- Gas exit temperature $\approx 300°$ F

From Figure 4-1, gas volume ≈ 150 ft.^{3} dry flue gas per 10^4 BTU fired. (Corrected to 60° F, 30" Hg).

Correcting to 300°F to get acfm,

$$\boxed{\text{Gas Volume} \cong 9.5 \times 10^3 \text{ acfm per ton/hr of coal fired}}$$

Reference 6 gives us a useful comparison with actual coal fired plants (Table 4-3). The comparison with the derived factor seems quite reasonable. For coal with a different heat content, multiply the derived factor by

$$\frac{\text{Heat Content, Millions of BTU's per Ton}}{26}$$

For plants burning oil and gas, the following factors apply:

OIL

Residual fuel oil, 35 percent excess air, 300°F gas exit temperature

$$\boxed{\text{Gas Volume} = \frac{48.5 \text{ acfm}}{\text{gal/hr of oil fired}} \times \frac{\text{Heat Content, } 10^5 \text{ BTU/gal}}{1.5}}$$

TABLE 4-2. GAS VOLUME FACTORS* (Reference 4)

PROCESS	GAS VOLUME PRODUCTION
Kraft Processes	
Recovery furnace	25000 acfm/100 tons per day air-dried pulp
Lime kiln	3200 acfm/100 tons per day air-dried pulp
Smelt-dissolving tank	3100 acfm/100 tons per day air-dried pulp
Bark boiler	8000 acfm/100 tons per day air-dried pulp
Aluminum Industry	
Prebaked cells	$7.15*10^4$ acfm/1000 tons of annual capacity
Soderberg cells	$1.14*10^5$ acfm/1000 tons of annual capacity
Phosphate Fertilizer	750 acfm (at 150°F) per ton-per-day plant capacity
Oil Refinery (Catalyst Regenerator)	Total acfm = $\frac{2830\ \text{acfm}}{1000\ \text{bbl/day}}$ x feed rate (1000 bbl/day)
Asphalt Batching	150 acfm per ton of mix per hour
Cement Industry	
Wet process	$40*10^3$ acfm per 1000 bbls/day
Dry process	$48*10^3$ acfm per 1000 bbls/day
Lime	
Rotary kiln	5500 acfm per ton/hour
Vertical kiln	3200 acfm per ton/hour

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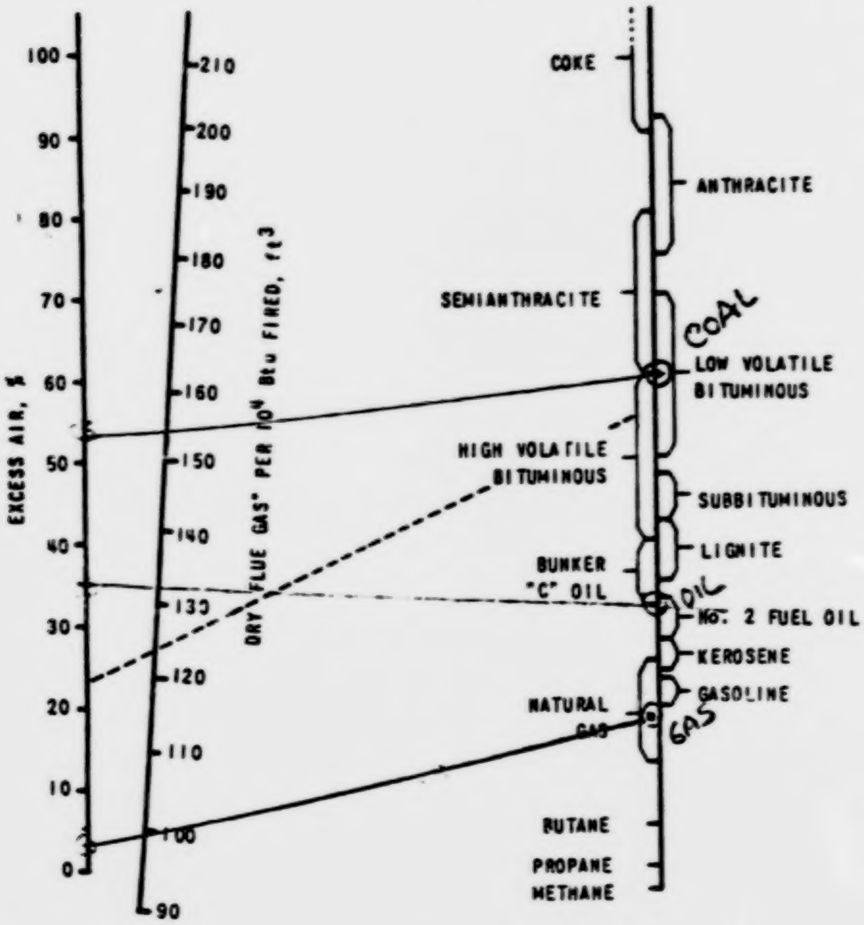
*Based on average conditions and various assumptions described in Reference 4.

Figure 4-1. Relationship between Type of Fuel Burned, Excess Air, and Resulting Volume of Combustion Products. (Reference 5)



* Volume corrected 60 °F and 30 in. Hg dry

TABLE 4-3. MEASURED GAS VOLUME FACTORS (Reference 6)

Type of Boiler Firing	Coal Rate, Ton/Hour	ACFM	$\frac{10^3\ \text{ACFM}}{\text{Tons/Hour}}$
●Vertical	65.6	549000	8.37
●Corner	56.1	518000	9.23
●Front-wall	52.2	453000	9.99
●Spreader-stoker	9.2	91900	8.67
●Cyclone	64.4	792300	12.30
●Horizontally opposed	9.6	92700	9.66

GAS

Natural gas, 3 percent excess air, 300°F gas exit temperature

$$\boxed{\text{Gas Volume} = \frac{.256\ \text{acfm}}{\text{ft}^3/\text{hr of gas fired}} \times \frac{\text{Heat Content, } 10^3\ \text{BTU/ft}^3}{1.05}}$$

In conclusion, the exhaust gas volume in acfm for fuel combustion sources may be calculated from an accurate estimate of the fuel rate with some reasonable degree of validity. It is also possible that acfm may be estimated accurately for most industrial processes given considerable details of the exact process and an accurate estimate of the process rate. However, the required level of detail and accuracy is not available in most Rapid Surveys. Given the close relationship (see Section 3.4.1) between exhaust gas volume and control device capacity (and cost), the importance of upgrading the variables which figure in the calculation of acfm is evident.

4.2.2 Fuel Data - Price, Sulfur Level, Heat Content

The accuracy of fuel data is a weak link in the modeling process. Users and dealers often do not know what the sulfur level and heat content of their fuel is, and obtaining accurate data is quite difficult. Also, because strict SO_2 regulations often demand widespread switching to low sulfur fuels, prices of such fuels are subject to fluctuation which cannot be accounted for in the IPP model.

Fuel heat content and price was not available in the Rapid Survey data, and sulfur content was only occasionally given. Therefore, region-wide averages were used in place of the missing data. Average values were obtained from *The Fuel of Fifty Cities* (Reference 7) and from the detailed files.

The gathering of this average data is not a straightforward process. Reference 7 rarely has only one price for a given fuel (since there are several sources of data and often several grades of the same fuel). Furthermore, there are four prices for most fuels--Domestic, Commercial, Indistrial, and Power Plant - and the price difference between the four is considerable. For instance, Reference 7 gives the following prices for coal in the St. Louis area:

Domestic $24-26 per ton
Commercial $21-24 per ton
Industrial $7.15 per ton
Power Plants $4.45 per ton

In general, a point source may be expected to pay "industrial" prices at the most; the names refer more to the level of fuel use rather than the actual business the source is in. However, depending on the size limitation placed on point sources in the inventory, it is conceivable that the smallest sources may be charged at rates higher than "industrial";

in addition, extremely large industrial sources might pay rates approaching "power plant" rather than "industrial" rates.

Another potentially confusing point is the difference in price between "interruptible" and "firm" gas prices. "The essential difference between the two classes is that the commercial user can be supplied without straining the system, while an industrial user will usually have some restriction on demand, for example, interruptible or dual fuel service, maximum daily limits, or the stipulation that the user be located on a major gas main," (Reference 7).

For point sources, "firm" prices are used when only gas is burned (it is assumed that a substitute fuel is impractical); when the plant burns several fuels, "interruptible" gas prices are assumed. In St. Louis, the "firm" price is \$.055 per therm, while "interruptible" services cost \$.033 per therm.

Although unavoidable, the use of region-wide averages is quite dangerous here. The effect that such use has on the results for individual sources ("MICROSCOPIC" result) is well known; if a plant is paying for fuel at a rate significantly different from the region-wide average, or else using a significantly lower or higher grade fuel than the average, cost results for control of the source can be considerably in error. However, it might be assumed that regional ("MACROSCOPIC") results will not suffer from the use of averages because these errors will balance out, i.e., some plants will be "charged" too little and some too much. This is not necessarily the case. A simple example will illustrate the possibility of a very significant error in the overall results:

- Assume region-wide average sulfur level of fuel is one percent
- Assume this average actually consists of:

  50 percent of the fuel contains .5 percent sulfur
  50 percent of the fuel contains 1.5 percent sulfur

If a maximum one percent fuel sulfur limitation is enforced in the region, the model will predict ZERO CONTROL COSTS and no improvement in the air quality of the region.

The scenario that is enacted here has the users of the high grade .5 percent sulfur fuel switching to a lower grade one percent fuel, which is highly unlikely. A more likely result might be a general maintenance of the higher grade usage among this group, coupled with a shift to one percent coal among the previous "1.5 percent" group, generating a very substantial cost of control and air quality improvement.

4.2.3 Stack Exit Temperature

Although exit temperature is not given in the Rapid Survey, it is an important variable:

- Given a calculated "standard gas volume flow" it determines actual flow rate according to the gas law.
- It can be a determining factor in control device selection. For instance, fabric filters are rated as to their heat tolerance. In the cost section of IPP, three selections of fabric filters are available according to exit temperature of the source.
- It is a factor in calculating the "plume rise" of the exit gas, and therefore plays a role in predicting air quality.

An attempt was made to derive an empirical relationship between exit temperature and gas volume (which is a measure of plant size) for combustion sources, using the available detailed inventories for data. It was expected that larger plants would be more efficient and thus have lower exit temperature. While some correlation seemed to be present in the Cincinnati inventory, further investigation of the Philadelphia and St. Louis inventories did not prove as fruitful. It was decided to assume a constant exit temperature of 300°F (422° K) for all combustion sources. Process source temperatures were obtained, where possible, as industry-wide averages from Reference 4. Judging from the values in the detailed files, deviation from these "averages" is high.

4.2.4 Rated Capacity

The particulate fuel combustion emission standard used in the report is based on the rated capacity, in BTU/hour, of the applicable plant. Although boiler capacity is listed in Section 4.1 as a variable to be collected, neither of the two rapid inventories contained rated capacity. Actual heat intake, in terms of the heat content of the fuel used, was therefore substituted in place of the correct values. This calculation is not likely to be very accurate, since few plants actually operate at their rated capacity. In addition, the value calculated will be an average heat input over the year whereas an estimate of the maximum heat input would be of more use for an estimate of rated capacity. The accuracy of this variable could be improved by the incorporation of an accurate "use factor" into the calculations.

An idea of the impact of an error in rated capacity can be obtained by inspecting the emission standard in Figure D-1 and noting that the rate of allowable emissions varies between .6 pounds per million BTU and .12 pounds per million BTU as the capacity rating of the emission source increases. A 100 percent error in rated capacity, which is not really a remarkable error when considering the difficulties of calculation, will result in an error in the allowable emission rate on the order of 30 percent or so.

4.2.5 Operating Hours

Most of the 305(a) (Cost of Clean Air) regulations are stated in terms of rates PER HOUR, whereas plant variables are normally given in the rapid inventory in terms of rates PER YEAR. An accurate measure of operating hours per year is therefore necessary to properly apply the regulations. Note that the calculation of rated capacity above is directly dependent on an accurate estimate of operating hours.

An inspection of the detailed emission source files of Philadelphia and Cincinnati revealed that there exists a pattern of operating hours/year for most industry groups. Although quite a bit of "scatter" exists, it seemed reasonable to construct a table of operating hours per year versus industry groups for use in constructing the source file for the Rapid Survey data (see Table 4-4).

Emission rates for air pollution source inventories are calculated on an "average annual" basis: Emission in tons/year is simply divided by 365. In this manner, a summation (over all sources) of "average annual" daily emissions will give a reasonable picture of the average emissions on

TABLE 4-4. OPERATING HOURS

SIC Code (two digit)		Operating Hours Per Year
20		8760
25		5840
26		8760
27		5840
28		8760
29	11 oil refineries	8760
	51 asphalt batching	4380
32		8760
33	non-foundry	8760
	foundries	4380
34		5840
35		5840
37		8760
4911		8760
4953		7300
80	except hospitals	5840
	hospitals	8760
82		5840
99		7300

a given day. A summation of emissions calculated on an "emission/operating day" basis will be larger than that of an actual average day, because on any given day some plants will be shut down. (The use of "average annual" emissions is an approximation because plant shutdown is not a random affair; usually more plants shut down on weekends, or during certain seasons, so that an average Sunday will have less air pollution than an average Wednesday.) During the course of constructing the source files, it was discovered that several discrepancies existed between fuel sulfur content, fuel use, and SO_2 emissions in the Rapid Survey data. The three factors are linearly dependent; for instance, in coal combustion,

$$SO_2 \text{ emissions, Tons/Year} = .019\ S \times (\text{coal rate, Tons/Year})$$

where S = percent by weight of sulfur in coal

It was found that daily "average annual" SO_2 emission rates did not agree with the formula. Apparently, yearly emission rates had been correctly calculated, but had then been divided by actual operating days rather than 365 to obtain daily rates. Extensive corrections were then made, especially in the St. Louis file; the result is that both the St. Louis and Cincinnati emission inventories used in this study no longer agree with those originally found in the Rapid Surveys.

4.2.6 Source Identification

The eight digit Source I.D. used to identify each emission source in the IPP source inventory consists of the following:

- a four digit Standard Industrial Classification (SIC) code number
- a three digit site number
- a one digit process-detail code

In many cases, the plant descriptions in the Rapid Surveys are of insufficient detail to precisely identify the proper SIC code or process-detail code (the latter code identifies the process--fuel combustion, open hearth furnace, sinterer, electric arc, etc., etc.--given the SIC code). The result is that a proper choice of control devices cannot be made. It is expected that some of these omissions are the result of data handling problems rather than a lack of collecting these data in the first place. The original calculation of annual emissions must have been based on a knowledge of process details.

The lack of precise details of the process type (or, in the case of fuel combustion sources, of the equipment used) can lead to serious errors in the emission estimates. Table 4-5 reproduces table F6 in Reference 3. The table explains why the Rapid Survey and Detailed Inventory particulate estimates in Tables 5-1 and 5-2 are so often not in agreement; a wrong guess about combustion equipment can result in a substantial error in the emission calculation.

4.2.7 Existing Control Equipment

The Rapid Surveys contain only very sketchy details of existing particulate and SO_2 control devices. Where any data appears, it is invariably in the form of either a control efficiency or a device name. The latter is undoubtedly the more reliable of the two. It is probable that a considerable number of air pollution control device users have no way of telling just how efficient their devices are, especially after a few years of use and the accompanying degradation of efficiency due to imperfect maintenance, wear and tear, etc. In the cases where only a device name was given, an attempt was made to find an average value for that device's efficiency; this value was used in the source inventory. Reference 3 contains some useful information on this subject.

A knowledge of the present level of control is particulately important in the application of the 305(a) standards to incinerators. The particulate solid waste disposal standard is a curve of potential emission versus allowable emission. The model uses present emissions and control efficiency to calculate potential emissions:

$$\text{potential emissions} = \frac{\text{present emissions}}{1 - \text{control efficiency}}$$

Neither the control efficiency nor the control device name, if any, is given for the incinerators listed in the St. Louis and Cincinnati Rapid Survey data. Control efficiency is therefore assumed to be zero for these sources.

TABLE 4-5. PARTICULATE EMISSION FACTORS FOR COAL COMBUSTION (WITHOUT CONTROL EQUIPMENT); (Reference 3)

Type of Unit	Particulate Emission Lb/Ton of Coal Burned
Pulverized - General	
Dry Bottom	16A*
Wet Bottom	17A
Without Reinjection	13A
With Reinjection	24A
Cyclone	2A
Spreader Stoker	
Without Reinjection	13A
With Reinjection	20A
All Other Stokers	5A
Hand-Fired Equipment	20A

*A equals percent ash in coal (by weight).

4.2.8 Source Location

The identification of accurate emission source locations is an important factor in obtaining an accurate regional air quality pattern. A comparison of rapid and detailed source inventories reveals that the measurement of plant locations has been inaccurate in one or the other (or both). For example, since both the St. Louis rapid inventory and detailed inventory have been set up in Cartesian coordinates (with different origins), the difference between the two X coordinates (or Y coordinates) of any point should be a constant throughout the region .....since this is a linear measurement. Table 4-6 compares the locations of several power plants and indicates the "constant" conversion factor to switch between coordinate systems.

Ignoring the discrepancy between X coordinates for the Portage Des Sioux plant, which is possibly due to a data handling error, the locational error in the X coordinate can be as high as 2 kilometers, a severe error. The Y coordinates seem to be an order-of-magnitude more accurate.

Although it is not possible to state with confidence precisely what order of effect this error will have on predicted air quality patterns, this type of error contains the potential for creating high pollutant concentration "hot" spots where they do not exist (or hiding them when they do).

4.2.9 Stack Height

An accurate estimate of stack height is necessary for proper computation of air quality levels, since this parameter enters directly into the diffusion equation. The Rapid Surveys did not include this data; in most cases, point source stack heights were assumed to be 75 meters (with a very few obvious exceptions such as quarries). Area source stack heights were assumed to be zero. Although the inaccuracy of this data will hurt the analysis of St. Louis and Cincinnati, stack height should not be a difficult variable to obtain. Upgrading of other Rapid Surveys to include this variable should be a simple matter.

TABLE 4-6. LOCATION OF ST. LOUIS POWER PLANTS

PLANT	X_D*	X_R	(X_D-X_R)	Y_D	Y_R	Y_D-Y_R
MERAMEC	138.00	77.29	60.71	192.6	41.94	150.66
ASHLEY	151.21	88.94	62.27	218.6	68.20	150.40
CAHOKIA	150.6	88.86	61.74	215.0	64.46	150.54
VENICE	151.5	89.37	62.13	222.0	71.31	150.69
PORTAGE DES SIOUX	141.5	75.43	66.07	249.5	99.09	150.41

* X_D = detailed inventory X coordinate, kilometers

X_R = rapid survey X coordinate, kilometers

X_D-X_R = "conversion factor" between two coordinate systems

4.2.10 Emission Sources with Multiple Stacks

Reference 3 suggests that a Rapid Survey should account for each stack in a plant separately. This procedure was not followed in the St. Louis and Cincinnati Rapid Surveys, and it is not often possible with the limited time and resources usually allotted to such surveys. On the other hand, the more exacting detailed surveys usually separate sources on a stack-by-stack basis.

Although this lack of detail will not adversely affect the accuracy of the existing air quality patterns calculated in the Rapid Survey, it will make a substantial difference in all calculations concerning the effects of the 305(a) standards. The particulate emissions standard for industrial process sources assigns a variable allowable emission rate to plants of varying capacity. The larger the plant, the more stringent the emission standard becomes. It is profitable, therefore, for the plant to have each stack considered separately, because the sum of allowable emissions calculated by this method is somewhat greater than the allowable emission of the plant if it were considered as a single source.

To test the variation in allowable emissions caused by the two interpretations of the standards (or by the two levels of detail in the source file), a sample calculation was made for the Champion Paper Company in Cincinnati. In the detailed inventory, the plant is considered as five separate sources. In the rapid inventory, it is considered to be one. To be certain we were calculating only the difference between the number of sources and that no extraneous differences crept in, the five sources in the detailed inventory were actually compared with a single source computed by combining the five. The standard applied is the Maryland Particulate Emission Standard (see Figure D-1). The relevant details of the five sources are shown in Table 4-7.

The allowable emission for the individual stacks sum to a total of 1.81. The allowable of the plant considered as a single source is 1.48 tons/day, an 18 percent difference.

Given the lack of detail, it is tempting to divide the source into five stacks of equal capacity and equal heat input as a first approximation to the detailed case. In fact, however, this approximation will produce

TABLE 4-7. CHAMPION PAPER COMPANY CHARACTERISTICS

STACK NUMBER	ALLOWABLE EMISSIONS, TONS/DAY	RATED CAPACITY BTU/HR	COAL USE TONS/DAY	COAL HEAT CONTENT BTU/TON
1	1.28	573×10^6	423	26
2	.26	131×10^6	60.3	26.6
3	.19	94×10^6	40	26.6
4	.04	100×10^6	10	25.4
5	.04	100×10^6	10	24.5

a maximum allowable emission. In the present case, the allowable based on this assumption is 2.12 tons/day, which represents approximately the same level of error, but now in the opposite direction.

An interesting by-product of this multiple source error is that the air quality effects of the more stringent interpretation of the emission regulation (the computation of the allowable emissions on a "total plant" basis) are better simulated by a source file which lacks boiler-by-boiler details, since IPP as it is presently constructed has no provision to "combine" multiple sources for the purpose of calculating allowable emissions. This lack of detail is, of course, a severe disadvantage in calculating control costs, because the Control Cost Model will proceed to apply a single stack device to a source which actually has several stacks. A substantial error would be present only if the cost of control for the device varied linearly with rated capacity and heat input and if the cost equation contained no constant term; this is probably never true.

4.3 IMPACT OF 305(a) EMISSION CONTROL STRATEGY

Tables 4-8 through 13 provide a summary of the effects of the 305(a) emission standards on the Cincinnati and St. Louis AQCR's (as represented by their Rapid Survey emission files). Tables 4-8 through 4-11 provide an industry by industry breakdown of emissions and costs; Tables 4-12 and 4-13 indicate the control device demands and costs for each device category. These tables are directly comparable to their detailed inventory counterparts in Section 3.

As in the detailed inventory results, the cost and emission breakdowns highlight the importance of a relatively small number of powerplants to the overall pollution control effort in the two AQCR's. In Cincinnati, powerplants produce 9 out of every 10 tons of SO_2 emission contributed by major plants, and 1 out of every 4 tons of particulates (this latter figure occurs only because powerplants already exert a degree of control over their particulate emissions). In St. Louis, the appropriate proportions are 6 out of every 10 tons of SO_2 and 3 out of every 10 tons of particulate matter. Powerplants will also spend a large share of the total regional cost of control, although in three of the four cases the cost effectiveness of the control devices is better than the regional average.

TABLE 4-8. EFFECTS OF REGULATIONS; CINCINNATI 305(a) SO_2 STRATEGY (RAPID SURVEY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON **REMOVED**
o Steam/Electric	5	4	6,638	905.2	295.1	231.1	27.0
o Commercial/Institutional Boilers	9	2	19	9.2	6.6	5.8	15.1
o Industrial Boilers	29	2	664	137.8	143.3	116.5	85.4
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	0	0	0	0	0	0	-
o Grey Iron	0	0	0	0	0	0	-
o Non-Ferrous Metals	0	0	0	0	0	0	-
o Sulfuric Acid	1	1	24	2.4	.2	.5	34.5
o Oil Refineries	0	0	0	0	0	0	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	0	0	0	0	0	0	-
o Fuel Combustion	43	8	7,321	1,052.3	445.0	353.4	28.7
o Industrial Process	1	1	24	2.4	.2	.5	34.5
o Solid Waste Disposal	0	0	0	0	0	0	-
o TOTAL	44	9	7,345	1,054.7	445.2	353.9	28.7

TABLE 4-9. EFFECTS OF REGULATIONS; CINCINNATI 305(a) PARTICULATE STRATEGY (RAPID SURVEY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON REMOVED
o Steam/Electric	6	4	1,178	50.4	30.6	13.0	86.3
o Commercial/Institutional Boilers	10	10	102	7.5	1.8	1.2	44.3
o Industrial Boilers	28	27	894	141.3	20.7	15.4	19.5
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	2	2	77	5.3	.8	.1	40.6
o Grey Iron	5	0	0	.2	.2	.2	-
o Non-Ferrous Metals	1	1	29	.2	.0	0	470.6
o Sulfuric Acid	0	0	0	0	0	0	-
o Oil Refineries	0	0	0	0	0	0	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	0	0	0	0	0	0	-
o Fuel Combustion	44	41	2,175	199.2	53.1	29.6	35.1
o Industrial Process	8	3	106	5.4	1.1	.2	56.0
o Solid Waste Disposal	6	6	63	6.4	1.6	1.4	34.2
o TOTAL	58	50	2,344	211.1	55.7	31.1	35.7

TABLE 4-10. EFFECTS OF REGULATIONS; ST. LOUIS 305(a) SO_2 STRATEGY (RAPID SURVEY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON REMOVED
o Steam/Electric	7	6	8,832	892.6	271.1	178.0	33.9
o Commercial/Institutional Boilers	8	8	1,737	44.5	14.1	4.7	119.8
o Industrial Boilers	29	22	11,748	266.9	276.5	116.5	214.0
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	0	0	0	0	0	0	-
o Grey Iron	0	0	0	0	0	0	-
o Non-Ferrous Metals	2	0	0	237.6	442.8	237.6	-
o Sulfuric Acid	4	4	353	69.8	4.6	14.0	17.3
o Oil Refineries	0	0	0	0	0	0	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	0	0	0	0	0	0	-
o Grain	0	0	0	0	0	0	-
o Varnish	0	0	0	0	0	0	-
o Other	2	1	19	21.0	2.4	19.4	31.9
o Fuel Combustion	44	36	22,316	1,204.0	561.6	299.3	67.6
o Industrial Process	8	5	372	307.4	447.4	251.5	18.2
o Solid Waste Disposal	0	0	0	0	0	0	-
o TOTAL	52	41	22,688	1,532.4	1,009.0	550.8	64.7

TABLE 4-11. EFFECTS OF REGULATIONS; ST. LOUIS 305(a) PARTICULATE STRATEGY (RAPID SURVEY)

SOURCE CATEGORY	TOTAL APPLICABLE SOURCES	TOTAL CONTROLLED SOURCES	COST 1000's OF $ PER YR.	EXISTING EMISSIONS TONS/DAY	ALLOWABLE EMISSIONS TONS/DAY	CONTROLLED EMISSIONS TONS/DAY	COST EFFECTIVENESS $ PER TON **REMOVED**
o Steam/Electric	7	5	1,066	123.2	28.9	15.8	27.2
o Commercial/Institutional Boilers	8	8	241	25.1	3.3	1.7	28.3
o Industrial Boilers	29	23	1,310	97.2	33.8	15.9	44.1
o Kraft Industry	0	0	0	0	0	0	-
o Iron and Steel	5	2	550	3.7	2.3	2.1	912.7
o Grey Iron	0	0	0	0	0	0	-
o **Non-Ferrous Metals**	2	1	173	5.7	.8	5.1	847.9
o Sulfuric Acid	5	2	87	24.4	2.1	1.1	10.2
o Oil Refineries	3	0	0	.3	2.5	.3	-
o Asphalt Batching	0	0	0	0	0	0	-
o Cement	2	2	148	3.9	.2	.1	107.3
o Grain	10	10	502	27.5	2.2	.3	50.6
o Varnish	1	0	0*	2.4	.1	2.4	-
o Other	11	8	394	67.5	3.7	10.9	19.1
o Fuel Combustion	44	36	2,617	245.4	66.0	33.4	33.8
o Industrial Process	39	25	1,854]	135.4	13.9	22.3	44.9
o Solid Waste Disposal	2	2	56	5.1	1.1	.2	30.9
o TOTAL	85	63	4,526	385.9	81.0	55.9	37.6

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*The only control for this source is a catalytic afterburner costing nearly 5 million dollars...this was judged impractical, as cost/ton ≈ $6,000.

TABLE 4-12. CINCINNATI DEVICE DEMAND AND COST, 305(a) STRATEGY (RAPID SURVEY)

DEVICE NAME	SO_2		PARTICULATES		TOTAL (Reconciled)	
	NO.SOURCES	COST, $/YR.	NO.SOURCES	COST	NO.SOURCES	COST
3 Wet Scrubber - Lo Eff.	0	0	6	63,200	6	63,200
8 Cyclone - Med. Eff.	0	0	15	142,500	15	142,500
9 Cyclone - Lo Eff.	0	0	10	115,500	10	115,500
10 Elect. Precipitator - Hi Eff.	0	0	1	29,200	1	29,200
12 Elect. Precipitator - Lo Eff.	0	0	3	1,394,100	3	1,394,100
13 Gas Scrubber	1	24,300	0	0	1	24,300
16 Fabric Filter - Hi Temp.	0	0	5	187,000	5	187,000
18 Fabric Filter - Lo Temp.	0	0	3	97,200	3	97,200
28 Fuel Subst., .8% S Coal	8	7,311,400	0	0	8	7,311,400

TABLE 4-13. ST. LOUIS DEVICE DEMAND AND COST, 305(a) STRATEGY (RAPID SURVEY)

	DEVICE NAME	SO_2		PARTICULATES		TOTAL (Reconciled)	
		NO. SOURCES	COST, $/YR.	NO. SOURCES	COST	NO. SOURCES	COST
7	Cyclone - Hi Eff.	0	0	4	65,200		
8	Cyclone - Med. Eff.	0	0	2	135,500		
10	Elect. Precipitator - Hi Eff.	0	0	7	1,395,000	6	855,200
11	Elect. Precipitator - Med. Eff.	0	0	3	552,900		
12	Elect. Precipitator - Lo Eff.	0	0	7	671,700		
13	Gas Scrubber	5	371,600	1	18,600	6	390,100
14	Mist Eliminator - Hi Velocity	0	0	1	63,400	1	63,400
15	Mist Eliminator - Lo Velocity	0	0	1	23,300	1	23,300
16	Fabric Filter - Hi Temp.	0	0	16	442,000	1	85,600
18	Fabric Filter - Lo Temp	0	0	18	948,800	18	948,800
32	Fuel Subst., 1% Sulfur Oil	13	11,172,500	1	2,700	13	11,172,500
33	Fuel Subst., Natural Gas	18	2,447,300	0	0	18	2,447,300
40	Alkalized Aluminum	1	2,616,000	0	0	1	2,616,000
42	Wet Limestone Injection	4	6,080,600	0	0	4	6,080,600

An interesting contrast between the two AQCR's is the importance of industrial sources of SO_2 emissions in the St. Louis AQCR as compared to their relative lack of importance in Cincinnati. The disparity is due mainly to the existence of several process sources of SO_2 in St. Louis as well as the use of low sulfur (1 percent) coal in Cincinnati's industrial boilers.

4.4 COMPARISON OF RAPID SURVEYS AND DETAILED INVENTORIES

In order to judge the quality of the results of the Rapid Survey IPP runs, they may be compared to those of the detailed inventory. Such a comparison should answer the following questions:

- How well does the Rapid Survey duplicate the detailed emission inventory?
- How well do the air quality estimates generated by the Rapid Survey diffusion model agree with those generated by the detailed inventory?
- How similar are the 305(a) impacts predicted by the Rapid Survey and detailed inventory?

4.4.1 Emission Inventory Comparison

Tables 4-14 and 4-15 compare the emissions of the major point sources in Cincinnati and St. Louis as recorded by the Rapid Surveys and the detailed inventories. An inspection of the tables reveals that the SO_2 estimates tend to be in reasonable agreement, with a few notable exceptions (Armco Steel in Cincinnati, for instance), whereas the particulate estimates display a wide variation. These results are not surprising, assuming a fairly good estimate of plant fuel use and fuel sulfur content. As noted in Section 4.2, particulate emissions from fuel combustion sources are strongly dependent upon the precise type of boiler used (see Table 4-5), while SO_2 emissions are solely a function of fuel use and sulfur content.

A comparison of the other important variables in the "source files" would be quite tedious here. The major problem areas were pointed out in Section 4.2 to be:

- Operating hours.
- Fuel data--sulfur and ash contents, prices.
- Stack data.

TABLE 4-14. EMISSION INVENTORY COMPARISON, CINCINNATI MAJOR POINT SOURCES*

	SO_2 Emissions (Tons/Day)		Particulate Emissions (Tons/Day)	
	Detailed Inventory	Rapid Survey	Detailed Inventory	Rapid Survey
Power Plants	961.33	905.23	225.28	50.24
• Tanners Creek	339.30	437.00	64.75	15.90
• Beckjord	452.52	308.60	29.62	20.31
• Miami	162.20	137.58	125.99	12.07
• Reading	1.10	.50	.09	.07
• Hamilton	6.21	21.55	4.83	1.89
Sorg Paper (Boiler)	4.03	3.70	12.50	12.40
Champion Paper (Boiler)	15.73	10.40	3.37	10.50
Proctor and Gamble (Boiler)	6.08	8.92	4.72	6.20
Dupont Sulfuric Acid	14.20	-	0	-
Philip Carey (Boiler)	2.38	3.13	7.35	7.89
General Electric (Boiler)	3.64	3.12	9.22	1.57
Interlake Steel (Electric Arc)	0	0	13.00	1.50
Armco Steel (Boiler)	11.77	82.20	5.48	68.50
Armco Steel (Open Hearth)	0	-	32.87	-

*(Not a complete list.)

TABLE 4-15. EMISSION INVENTORY COMPARISON, ST. LOUIS MAJOR POINT SOURCES*

	SO_2 Emissions (Tons/Day)		Particulate Emissions (Tons/Day)	
	Detailed Inventory	Rapid Survey	Detailed Inventory	Rapid Survey
Power Plants	1030.41	1009.44	189.00	137.78
• Ashley	46.20	38.89	11.45	4.98
• Wood River	249.73	248.80	120.42	95.30
• Mound	-	.25	-	.02
• Meramec	358.00	377.10	9.76	12.00
• Cahokia	40.30	31.90	4.68	4.00
• Venice	115.00	116.80	36.61	14.91
• Highland	4.18	3.60	.48	4.60
• Portage Des Sioux	217.00	192.10	5.60	1.97
St. Jo Lead Smelter	232.00	232.23	.61	.59
Coking Plant	17.30	-	30.80	-
Brewery	-	17.90	-	2.29
CKW Chemical Plant (Boiler)	8.56	7.18	14.67	9.17
National Lead (Boiler)	22.00	20.26	7.30	3.90
Monsanto (Boiler)	32.80	31.69	10.70	19.26
Alpha Cement	0	0	1.09	1.90
Chrysler (Boiler)	5.80	4.74	2.52	6.05

*(Not a complete list.)

- Gas exit volumes, temperature, and velocity.
- Plant rated capacity.
- Process and equipment details.

Table 4-16 compares the recorded regional emissions of the emission source files for Cincinnati and St. Louis. The results for St. Louis are excellent; emission estimates agree quite closely in every emission category. Note that a comparison between the number of sources in each source file must take into account the greater detail of the detailed inventory, which counts every stack as a separate source. For instance, most of the powerplants are registered as single sources in the Rapid Survey and as multiple sources in the detailed survey. (Comparisons in Tables 4-14 and 4-15 take this into account by adding up the separate stack emissions.)

The results for Cincinnati are quite poor. The Rapid Survey missed most of the industrial process and solid waste disposal sources, and apparently severely underestimated the particulate emissions of the major sources (see Table 4-14). The data for Cincinnati contained far less equipment detail than did the St. Louis data, and thus was subject to the variance in particulate emissions rates noted above.

4.4.2 Air Quality Estimates

In order to test the validity of diffusion model results generated by the Rapid Survey emission estimates, comparisons of the Rapid Survey-based and detailed inventory-based results were made in two different ways.

4.4.2.1 Rapid Survey versus Detailed Inventory - Direct Comparison

A direct comparison of the two sets of results was conducted. Using uncalibrated results (i.e., air quality estimates prior to being adjusted or "calibrated" by actual physical measurements of pollutant concentrations), plots were made using the Rapid Survey concentrations as the dependent variable (y) and the corresponding detailed inventory concentration as the independent variable (x). Each point on the plot then represents the Rapid Survey-based and detailed inventory-based pollutant concentrations at a single receptor. If the detailed inventory and Rapid Survey are identical, the plot will simply be a straight line through the origin with a slope of 1. If some systematic linear bias between the two exists, a positive or negative y-intercept and/or a slope other than 1 will result; however, this

TABLE 4-16. COMPARISON OF RAPID AND DETAILED EMISSION INVENTORIES /REGIONWIDE

	REGIONAL EMISSIONS (TONS/DAY)						NUMBER OF SOURCES			
	POINT	AREA	FC	IP	SW	TOTAL	FC	IP	SW	TOTAL
CINCINNATI										
PARTICULATES										
DETAILED INVENTORY	386.7	212.6	296.0	68.3	22.4	599.3	71	34	20	125
RAPID SURVEY	211.1	158.8	199.2	5.4	6.4	369.9	44	8	6	58
SO_2										
DETAILED INVENTORY	986.1	369.4	962.5	23.5	0	1,355.5	71	6	0	77
RAPID SURVEY	1,054.7	104.3	1,052.3	2.4	0	1,159.0	43	1	0	44
ST. LOUIS										
PARTICULATES										
DETAILED INVENTORY	446.8	108.3	309.5	130.3	7.3	555.1	47	60	3	110
RAPID SURVEY	385.9	92.2	245.4	134.4	5.1	478.1	44	39	2	85
SO_2										
DETAILED INVENTORY	1,631.7	46.2	1,306.7	324.9	0	1,677.9	46	13	0	59
RAPID SURVEY	1,532.4	157.7	1,204.0	328.4	0	1,690.1	44	8	0	52

bias will disappear after calibration and the two models will predict air quality in an identical manner. If the data points are scattered around a line, the final air quality predictions of the two models will differ.

In this analysis, lines were fitted through the plots using a least squares regression technique (identical to that used in calibrating the diffusion model) and the correlation coefficients and standard errors of estimate* were calculated. In addition, the values of the correlation coefficient representing the 95 percent confidence level for correlation were calculated for each case. Table 4-17 presents the results of the above computations. The magnitude of the Cincinnati correlation coefficients can be considered as the more significant since they are based on more data points. Figures 4-2 through 4-5 present the plots of the points and the regression lines. The values in Table 4-17 and the amount of scatter evident in the figures suggests that the Rapid Survey predictions of air quality are likely to be of limited accuracy. Although 3 out of 4 correlation coefficients are higher than those required for 95 percent confidence of correlation, the magnitude of the coefficients is quite low and the standard error of estimate is very high.

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* The (correlation coefficient)^2 predicts the fraction of the variation of the dependent variable y that is accounted for by the regression on the independent variable x. For instance, $R^2=.99$ means that the regression of y on x accounts for 99 percent of the variance of y. The remaining 1 percent is due either to other variables affecting y which are not included in the analysis or else to a nonlinearity in the function $y=y(x)$ not accounted for in the linear regression. In physical terms, $R^2=.99$ means that the other variables and/or the nonlinear term in $y(x)$ do not have much real effect and can be ignored in all but the most sensitive applications where small errors can be critical. Note that the R measured in this analysis is only an approximation of the true value of the correlation coefficient; the greater the number of data points used in the regression, the closer the measured R is likely to be to the true value.

The standard error of estimate measures the scatter in the vertical (y) direction of the data points about the regression line.

TABLE 4-17. CORRELATION BETWEEN RAPID SURVEY AND DETAILED INVENTORY AIR QUALITY PREDICTIONS

Run	#Points	R(.95)	R (Measured)	Standard Error of Estimate
Cincinnati SO_2	44	.294	.467	75.0
Cincinnati Particulate	44	.294	.641	34.6
St. Louis SO_2	22	.418	.531	102.8
St. Louis Particulate	14	.514	.281	123.1

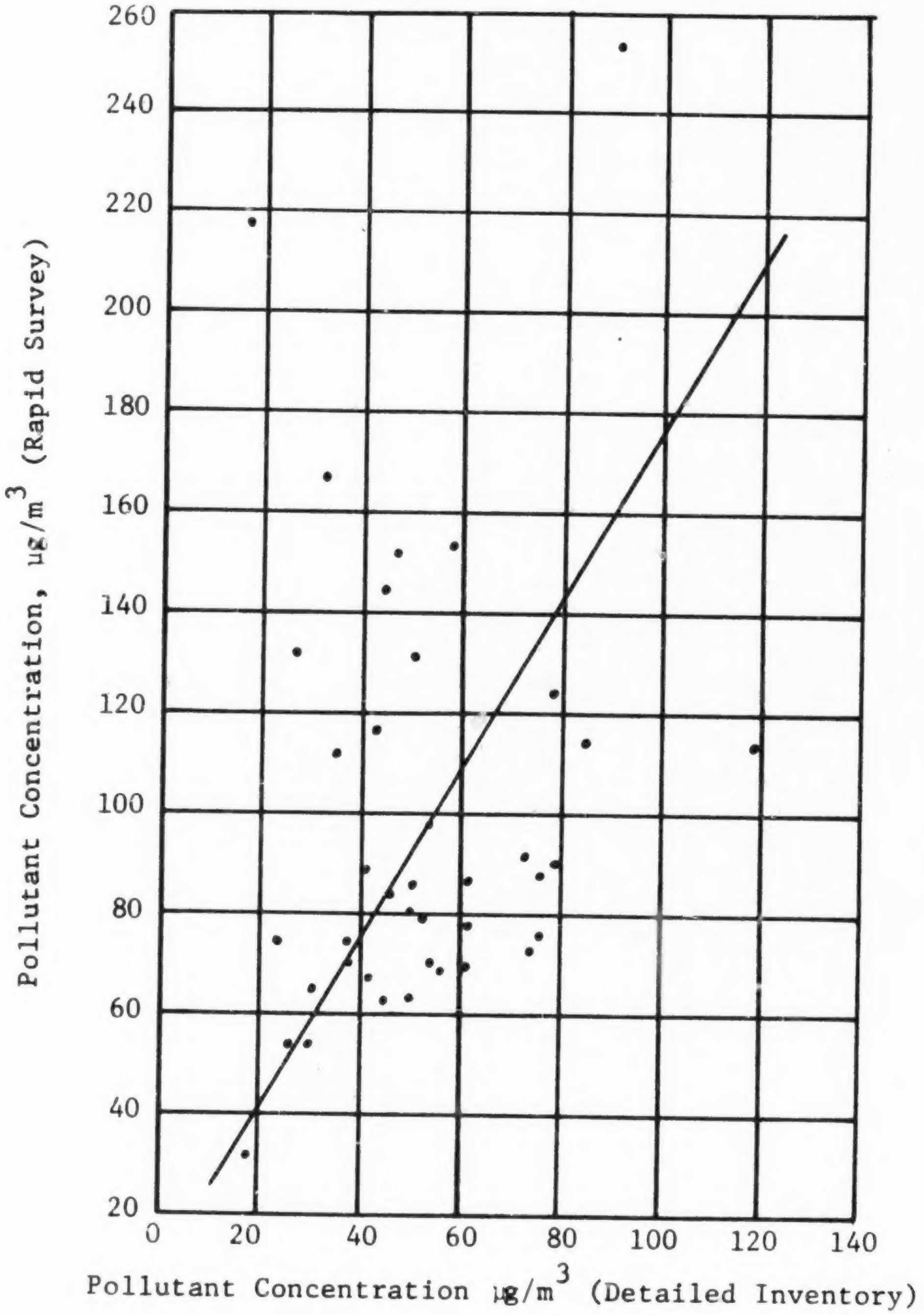

Figure 4-2. Scatter Diagram and Regression Line of Pollutant Concentration Estimates, Rapid Survey versus Detailed Inventory, Cincinnati SO_2

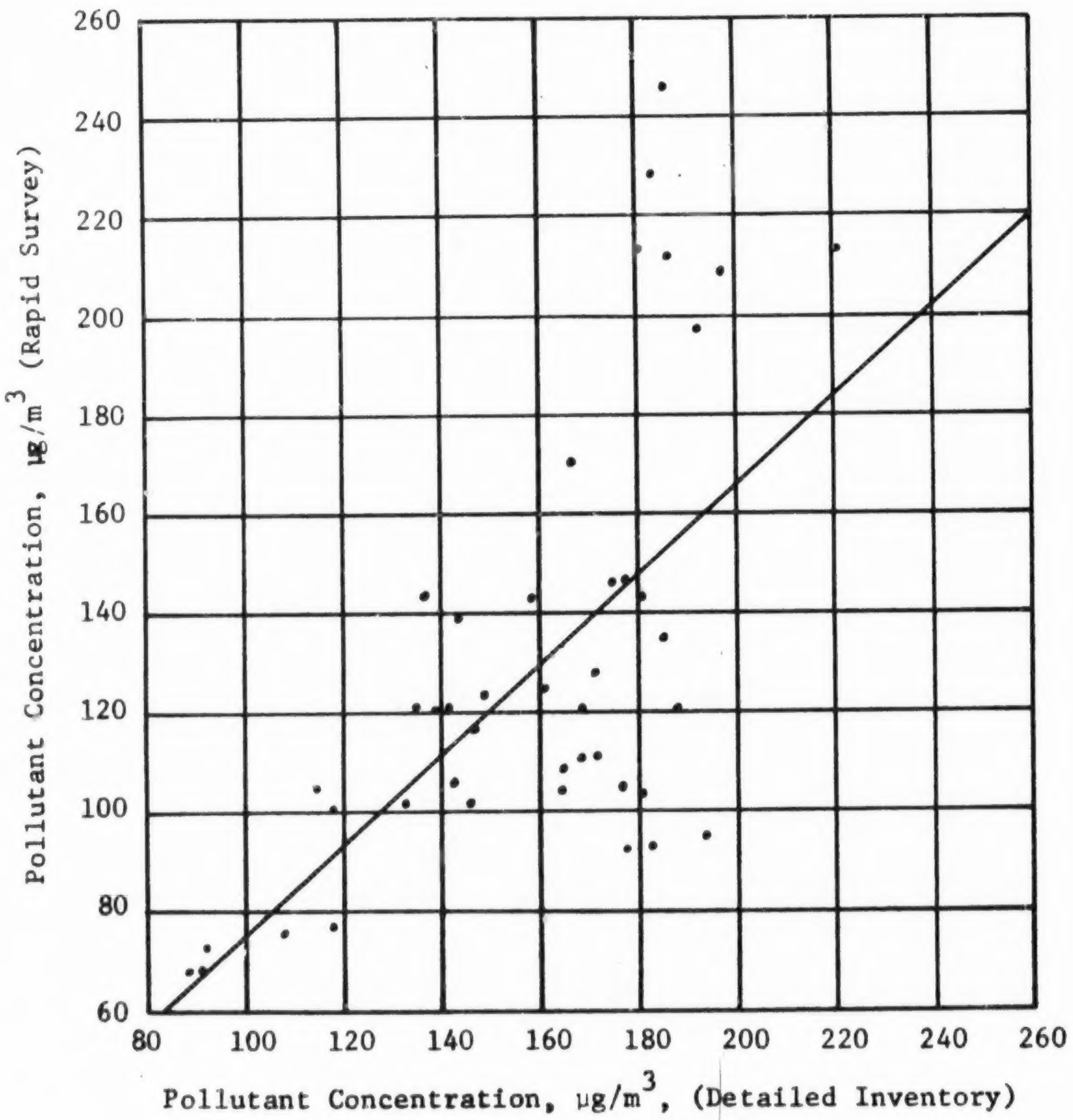

Figure 4-3. Scatter Diagram and Regression Line of Pollutant Concentration Estimates, Rapid Survey versus Detailed Inventory, Cincinnati Particulates

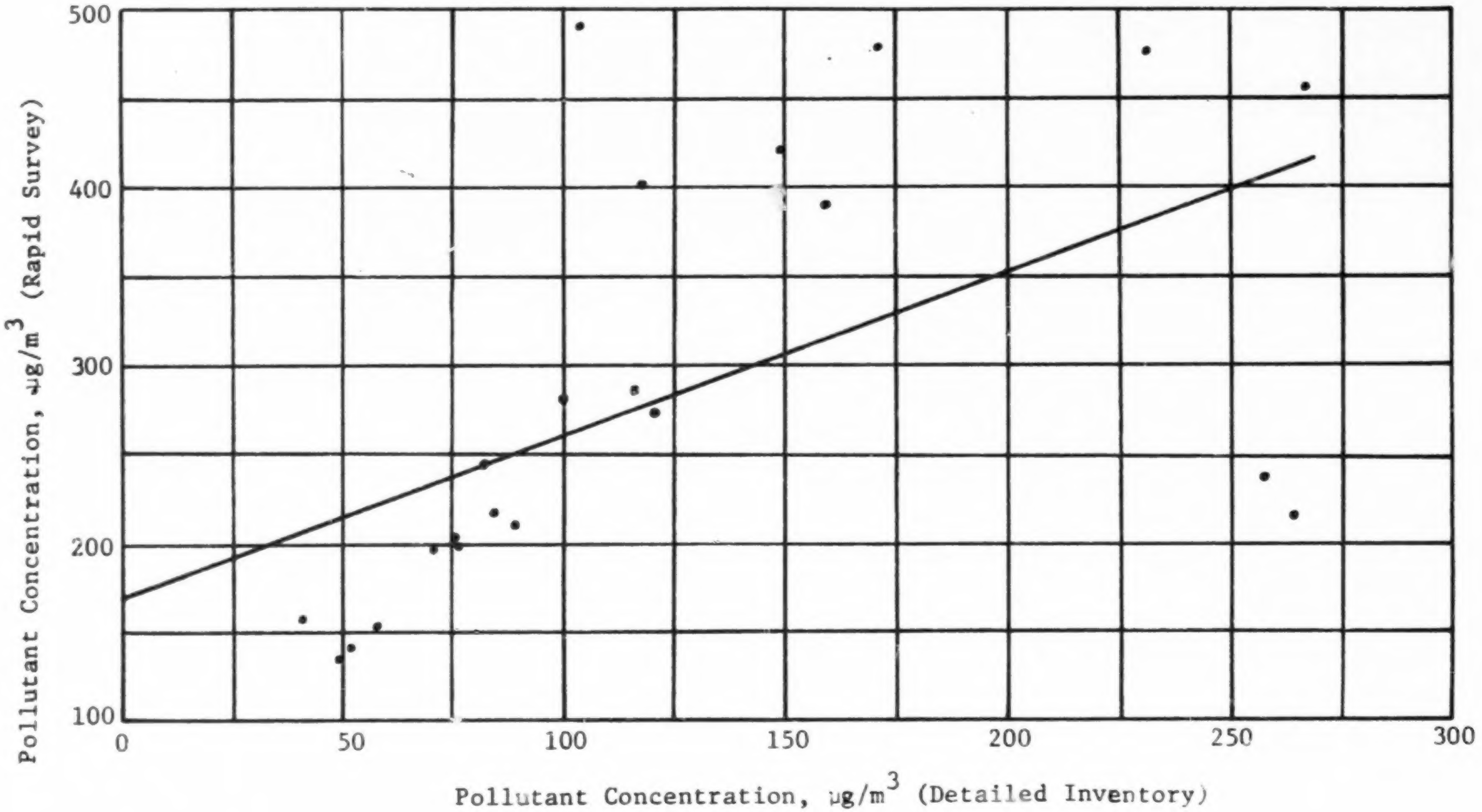

Figure 4-4. Scatter Diagram and Regression Line of Pollutant Concentration Estimates, Rapid Survey versus Detailed Inventory, St. Louis SO_2

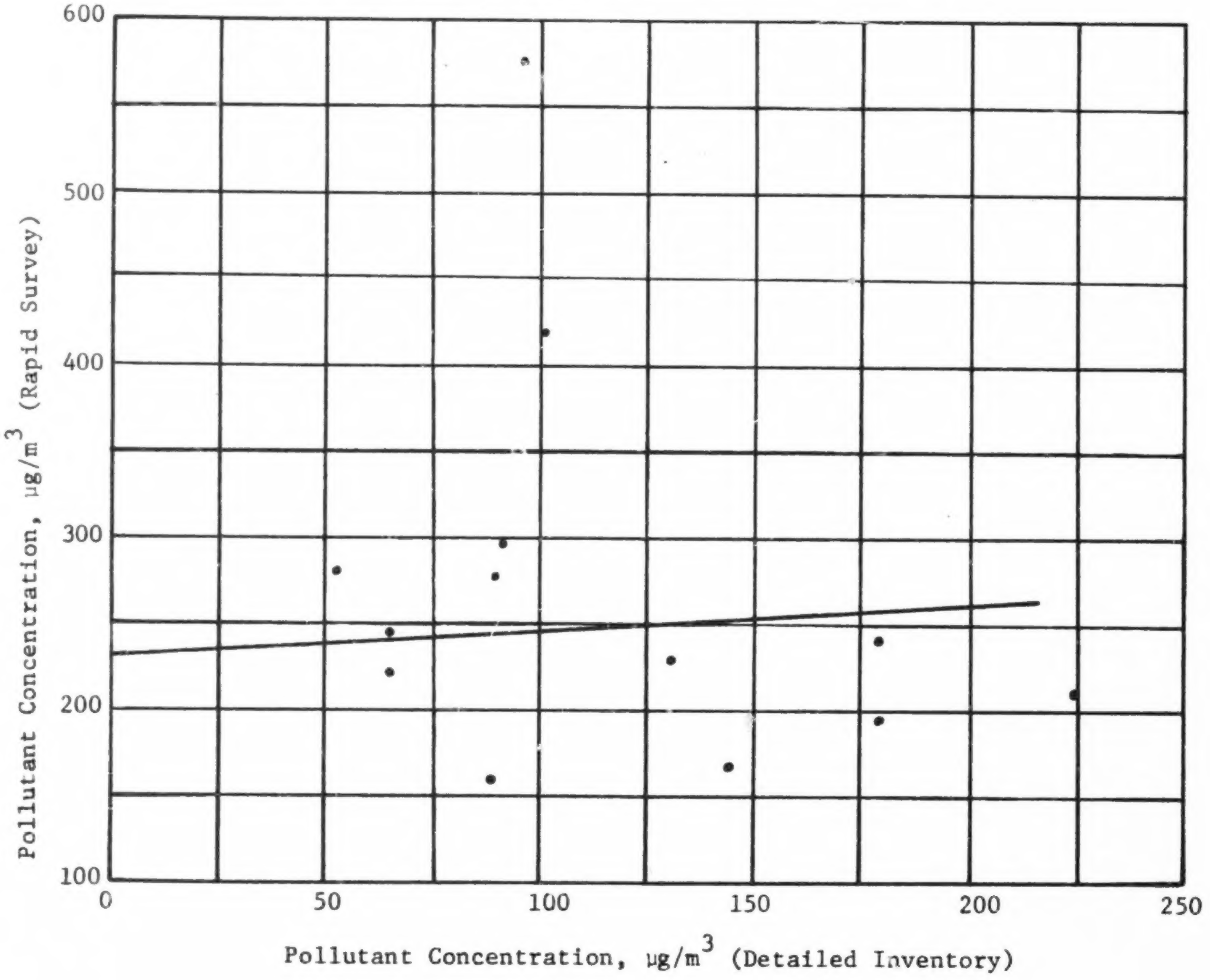

Figure 4-5. Scatter Diagram and Regression Line of Pollutant Concentration Estimates, Rapid Survey versus Detailed Inventory, St. Louis Particulates.

4.4.2.2 Comparison of Rapid Survey and Detailed Inventory Calibration

The calibration procedure for the diffusion model, where the results of the theoretical model are adjusted by comparing them to actual pollutant concentration measurements, provides a good test of the validity of the input data and the model itself. If very low correlation exists between the calculated air quality and the measured concentrations, then the diffusion procedure is invalid. Assuming accurate physical measurements, a low correlation can be an indication of serious errors in the original emission estimates.

An obvious test of the efficacy of the Rapid Survey's capabilities for air quality prediction in comparison to that of the detailed inventory is to compare the results of such calibration runs for both data sets. The appropriate calibration runs were conducted, and the correlation coefficients and standard errors of estimate are given in Table 4-18. The clear superiority of the detailed inventory air quality estimates are evident from the considerable differences in correlation between the two data sets, and the lower scatter as evidenced by the values of the standard errors of estimate.* Of particulate importance is the fact that none of the Rapid Survey results achieve the .95 confidence level of correlation, which is usually the minimum level required for continuing with the modeling studies.

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* It should be noted that the difference between the relative magnitudes of the standard errors of estimate in Table 4-17 and those in Table 4-18 is caused not by different degrees of "fit" of regression lines but merely by different "dependent variables." In Table 4-17, the dependent variable is the Rapid Survey data, whose range of values is high, whereas the dependent variable in Table 4-18 is the measured data, whose range is smaller. The standard error of estimate measures the vertical differences between the data points and the regression line; if the axes were rotated in the second analysis, the order of magnitude of the standard errors of estimate for the two tables would have been similar.

TABLE 4-18. RAPID SURVEY AND DETAILED INVENTORY CALIBRATION RUNS

Run	#Points	R(.95)	R*	Standard Error of Estimate
Cincinnati SO_2/Detailed	8	.666	.644	9.5
Cincinnati SO_2/Rapid	8	.666	.241	12.8
Cincinnati SO_2/Rapid, Adjusted**	7	.707	.371	13.9
Cincinnati Particulate/Detailed	34	.335	.762	14.6
Cincinnati Particulate/Rapid	34	.335	.282	21.6
St. Louis SO_2/Detailed	23	.404	.747	20.6
St. Louis SO_2/Rapid	22	.413	.548	25.7
St. Louis Particulate/Detailed	15	.497	.818	23.1
St. Louis Particulate/Rapid	14	.514	.282	41.8

*R(.95) = Correlation coefficient of .95 confidence level

R = Correlation coefficient

** = One data point was dropped because of extreme disagreement between measured and calculated concentration.

Figures 4-6 through 4-13 present the plots of the data points and corresponding regression lines for 8 of the 9 cases presented in Table 4-18. Three of the four regression lines corresponding to the Rapid Surveys are nearly horizontal; this indicates that the diffusion models are not accounting for the variation in air quality observed in the Air Quality Control Regions and are therefore relatively worthless. This result has strong implications regarding the utility of the Rapid Surveys for implementation planning; the aim of such planning is the achievement of air quality standards, and, in the case of St. Louis and Cincinnati, the Rapid Survey-based diffusion models could not have accurately predicted when such standards would be met.

There is a possibility of a bias in favor of the detailed inventories with regards to the diffusion model calibration runs. In the early calibration runs of the detailed inventories, attempts were made to increase the correlation of the results. Certain air quality measurements were thrown out of the calibration, because of suspicion of severe inaccuracies; measurements in extreme disagreement with the calculated values were obviously tempting targets for such removal. The Rapid Survey calibrations used the identical final measurement data as the detailed inventory, and did not have the benefit of such selective removal of data points. It is felt that the results of the calibration comparison are so firm that such favorable treatment would not have altered them significantly....in fact, the Cincinnati SO_2 calibration did drop one extremely unfavorable point (Figure 4-7), with no significant change in the results.

In addition, the primary cause for throwing out receptor measurements was the actual discovery of measurement problems with the instrumentation, and not merely the existence of a disagreement between calculated and measured ground level pollutant concentrations. However, the existence of this possible bias in the comparison should be recognized.

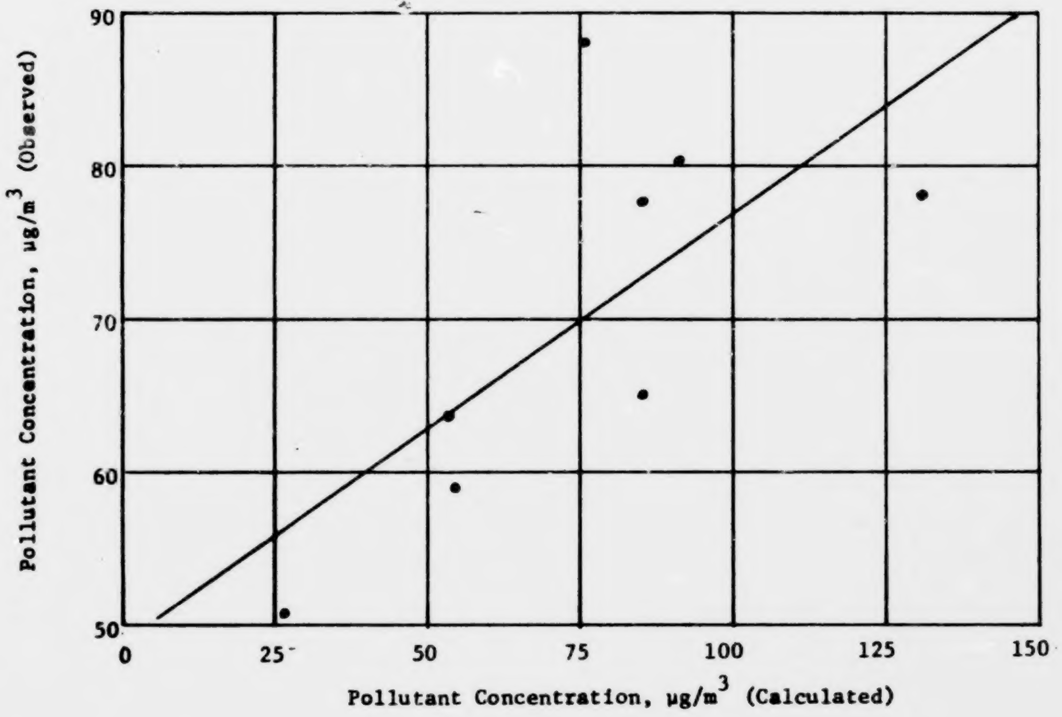

Figure 4-6. Diffusion Model Calibration Plot Cincinnati SO_2 (Detailed Inventory)

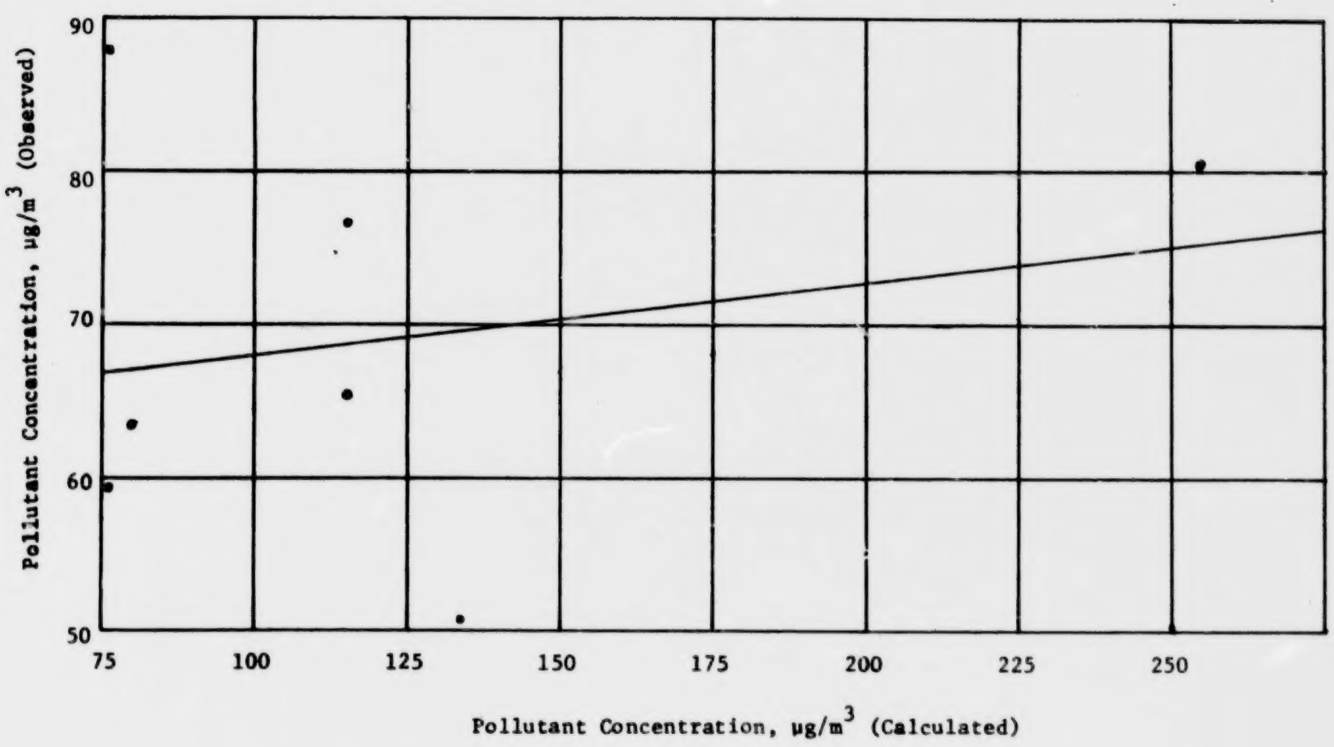

Figure 4-7. Diffusion Model Calibration Plot Cincinnati SO_2 (Rapid Survey, adjusted)

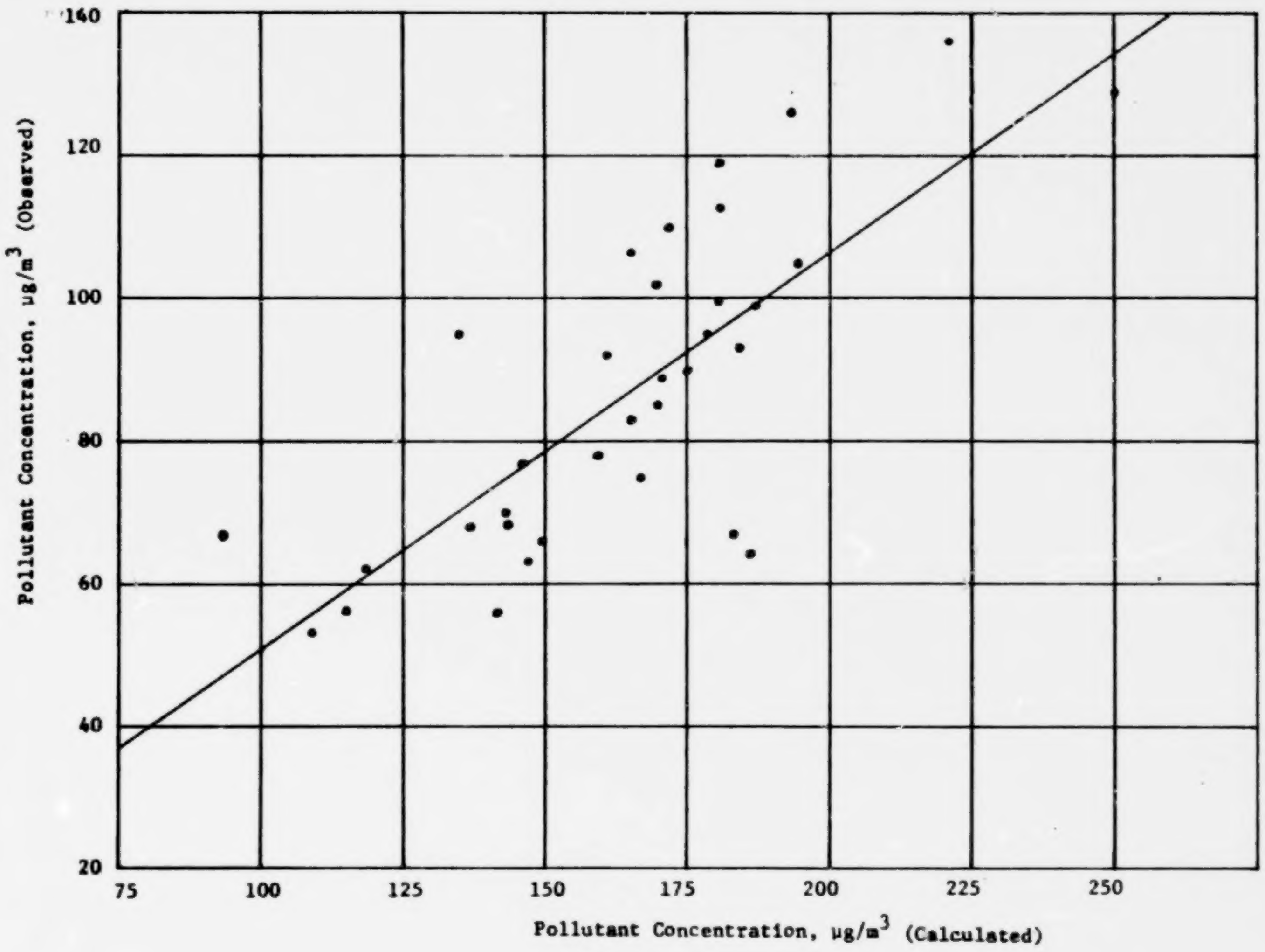

Figure 4-8. Diffusion Model Calibration Plot Cincinnati Particulate (Detailed Inventory)

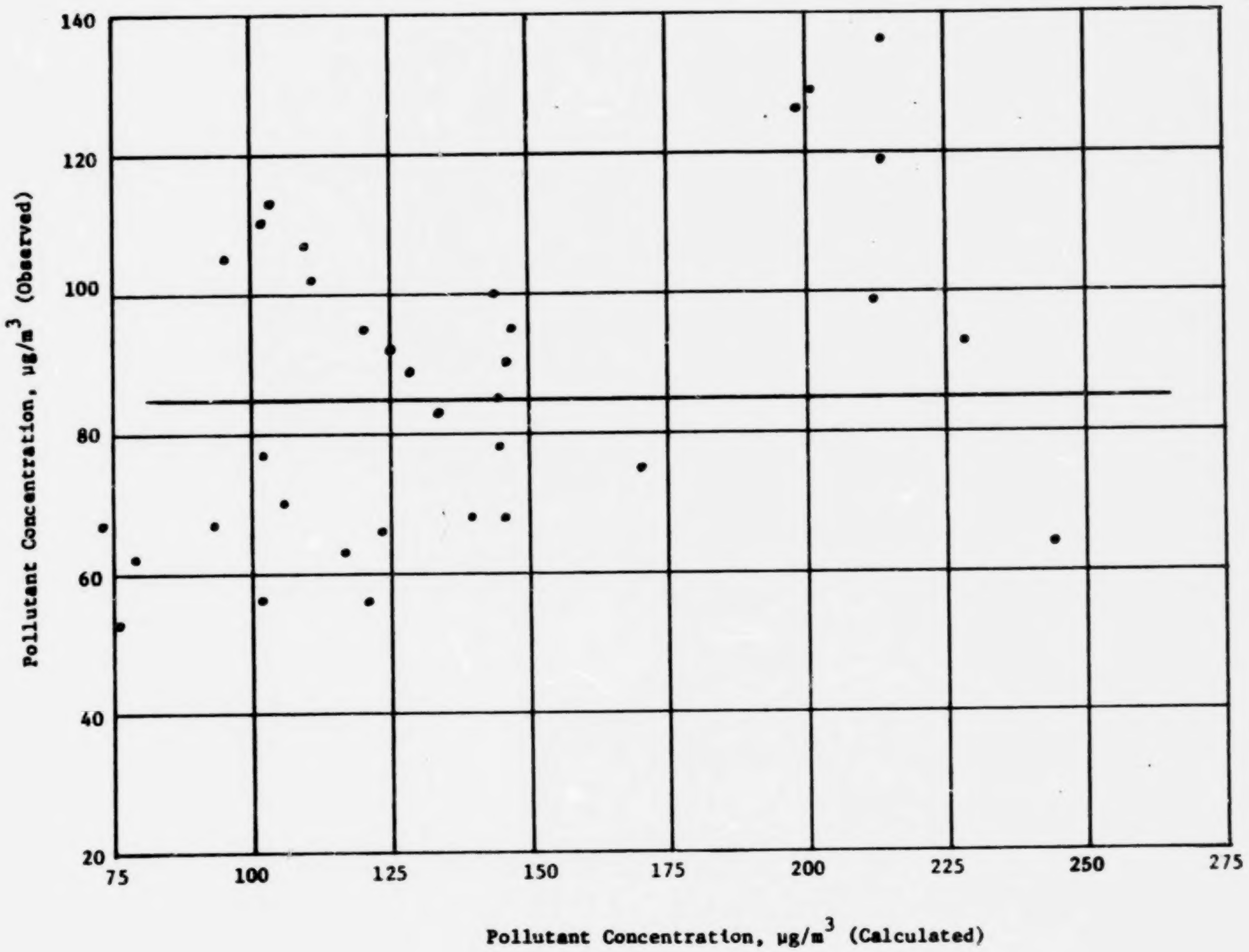

Figure 4-9. Diffusion Model Calibration Plot Cincinnati Particulate (Rapid Survey)

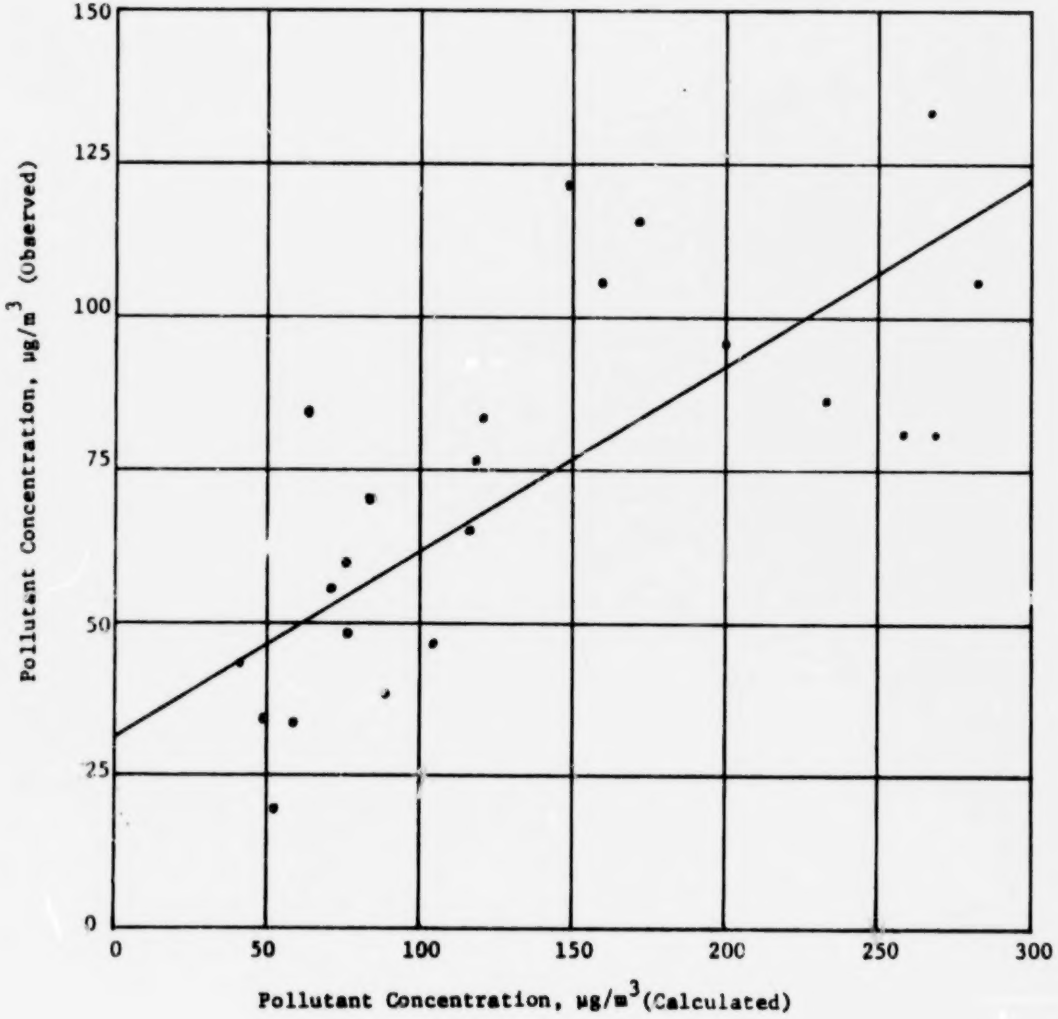

Figure 4-10. Diffusion Model Calibration Plot St. Louis SO_2 (Detailed Inventory)

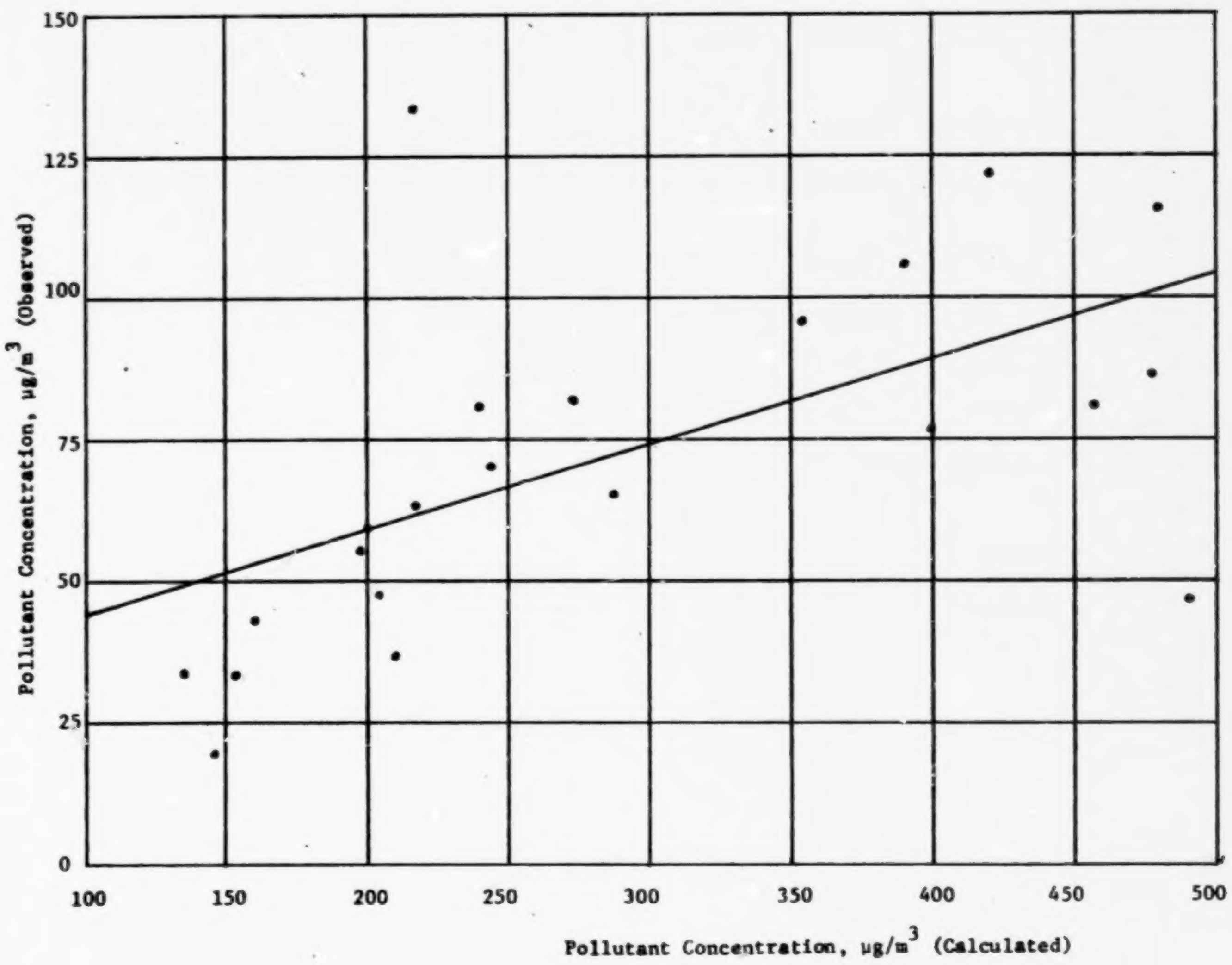

Figure 4-11. Diffusion Model Calibration Plot St. Louis SO_2 (Rapid Survey)

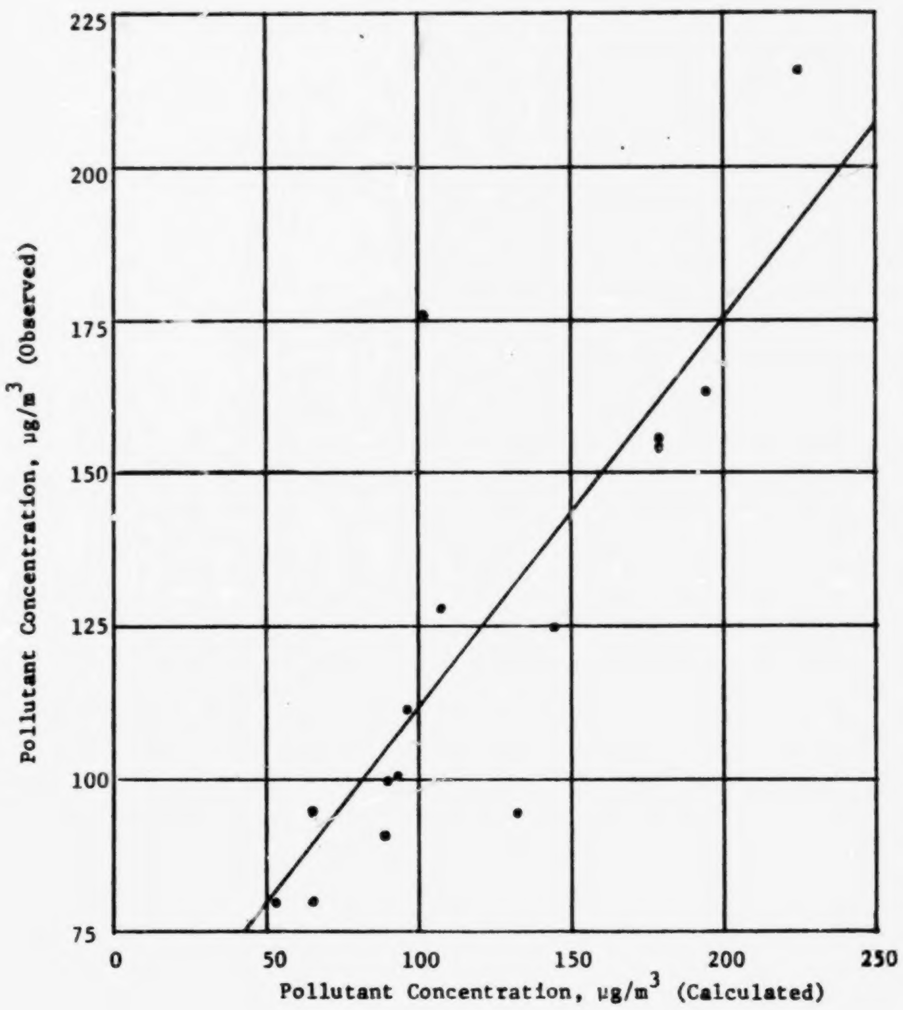

Figure 4-12. Diffusion Model Calibration Plot St. Louis Particulate (Detailed Inventory)

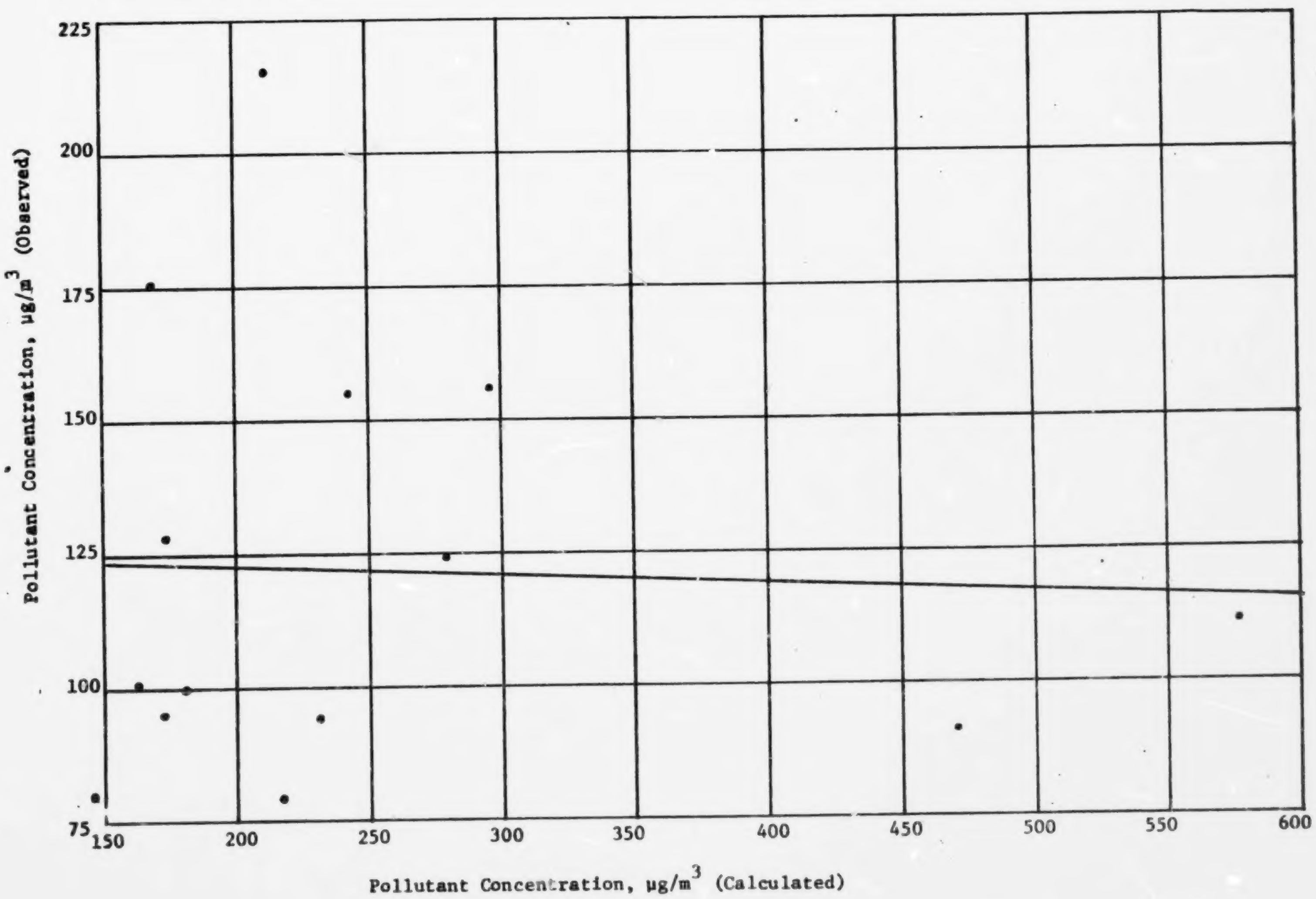

Figure 4-13. Diffusion Model Calibration Plot St. Louis Particulate (Rapid Survey)

4.4.3 Comparison of 305(a) Strategy Impacts - Detailed versus Rapid Survey Inventory

The key to the usefulness of the Rapid Surveys is their ability to predict the effects of various emission control strategies on the demand and cost of control devices and on air quality.

Accuracy in prediction of air quality effects can be inferred from:

- the level of accuracy of the pre-control air quality predictions (discussed in 4.5), and
- the accuracy of post-control emission predictions.

Table 4-19 indicates the post-control regional point source emissions and the percent reduction of emissions (caused by implementation of the 305(a) Strategy) for both the Rapid Survey and detailed inventory IPP model runs for St. Louis and Cincinnati. The level of agreement between the results of the two data collection methods is quite good, with the exception of the St. Louis SO_2 run.

Table 4-19 also compares the regional costs of the 305(a) strategies. There is no consistent pattern of accuracy apparent in the results. The only truly accurate cost prediction is that for SO_2 control in St. Louis, and the indicators of cost effectiveness and emission reduction for that case are relatively inaccurate. The extreme disagreement between the St. Louis particulate results is of particular significance, because the emission data of the Rapid Survey and detailed inventory are in reasonable agreement. The only possible source of error lies in the remaining source file variables (gas volume rate, previous level of emission control, etc., etc.).

Table 4-20 compares the device demands and costs generated by the 305(a) Strategy using the two data sources. Judging from the table, the Rapid Survey predicts the existence of major demands when they involve a number of sources, but is prone to miss expensive devices when they involve only one source. The Rapid Survey cost predictions are not generally very accurate (assuming that the detailed inventory predictions are), but they do show the major trends of device demands. This may be quite satisfactory for some purposes.

TABLE 4-19. COMPARISON OF 305(a) STRATEGY IMPACT ON POINT SOURCES

	EXISTING REGIONAL EMISSIONS (TONS/DAY) POINT SOURCES	CONTROLLED REGIONAL EMISSIONS (TONS/DAY) POINT SOURCES	PERCENT REDUCTION OF EMISSIONS	REGIONAL COST $/YEAR	NO. SOURCES		COST EFFECTIVENESS $/TON OF POLLUTANT REMOVED
					APPL.	CON-TROLLED	
CINCINNATI							
PARTICULATES							
DETAILED INVENTORY	386.7	42.9	89	3,338,000	125	83	26.6
RAPID SURVEY	211.1	31.1	85	2,344,000	58	50	35.7
SO_2							
DETAILED INVENTORY	986.1	306.5	69	3,969,000	77	30	16.0
RAPID SURVEY	1,054.7	353.9	66	7,344,900	44	9	28.7
ST. LOUIS							
PARTICULATES							
DETAILED INVENTORY	419.1	47.9	89	12,693,000	110	85	93.7
RAPID SURVEY	385.9	55.9	86	4,526,100	85	63	37.6
SO_2							
DETAILED INVENTORY	1,631.7	361.2	78	20,187,100	59	46	43.5
RAPID SURVEY	1,532.4	550.8	64	22,688,000	52	41	64.71

TABLE 4-20. COMPARISON OF MAJOR DEVICE DEMANDS OF 305(a) STRATEGY

	RAPID SURVEY		DETAILED INVENTORY	
	# SOURCES	COST, $/YR	# SOURCES	COST, $/YR.
ST. LOUIS				
• WET LIMESTONE INJECTION	4	6,000,000	8	10,900,000
• ALKALIZED ALUMINUM	1	2,600,000	0	0
• SWITCH TO NATURAL GAS	18	2,500,000	23	1,500,000
• SWITCH TO 1% SULFUR OIL	13	11,200,000	12	7,000,000
• FABRIC FILTERS	19	1,000,000	23	4,900,000
• ELECTROSTATIC PRECIPITATORS	8	900,000	8	1,700,000
• CATALYTIC AFTERBURNER	0	0	1	1,200,000
CINCINNATI				
• WET LIMESTONE INJECTION	0	0	1	1,200,000
• SWITCH TO .8% SULFUR COAL	8	7,300,000	31	2,600,000
• FABRIC FILTER	8	300,000	14	1,500,000
• ELECTROSTATIC PRECIPITATORS	4	1,400,000	15	800,000

5.0 THE 305(a) APPROACH

5.1 INTRODUCTION

The third method examined in this study for estimating control measure demand is called the "305(a) Approach." This name has been selected since the demand estimating procedure utilizes engineering data and control cost estimates from the Economics of Clean Air (ECA) Report*, (an annual economic report from the Administrator of the Environmental Protection Agency to Congress, required by Section 305(a) of the Clean Air Act of 1967).

The 305(a) Approach is unlike the Aggregation and Extrapolation approaches in that the IPP model is not used for predictive purposes. None of the models developed by TRW under this contract are used in the Approach. The method was selected because it is simple and uses data which is currently available. Also, the method provides a basis for comparison with the two other approaches which are based on the utilization of the IPP model. Finally, by analyzing the data in the Report at the regional level, better insight into the methods employed in making national control cost estimates is made possible. In other words, this analysis provides the reader the opportunity to observe the pertinent factors which may contribute to deficiencies in the ECA Report control cost estimates.

To prevent confusion, it is important that a distinction be made between the goals of the ECA Report and the objectives of this report. The ECA Report evaluates the costs resulting from the implementation of emission control regulations stimulated by the Clean Air Act, as amended. In addition, the impact of the control costs on specific industries is analyzed. The analysis includes the effect of the control costs on prices in the economy. Finally, expected price changes in specific industries are analyzed with the use of an input-output model, and price level increases are predicted for the automobile and construction industries.

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* - The Economics of Clean Air. Report of the Administrator of the Environmental Protection Agency to the Con ress of the United States, U. S. Government Printing Office, March 1971.

The goal of this study is to more closely examine the specific resources demanded by such legislation by identifying and categorizing the specific control systems and fuel substitutions. New legislation for the control of air pollution stimulates a demand for a complex mix of resources. This is unlike some legislation which stimulates or depresses the market for only one specific good. The promulgation of emission control regulations requires a combination of resources which include specific types of fuel, control hardware, construction equipment, labor, electric power, and numerous others.

The 305(a) Approach has been developed to provide decision-makers with estimates of the resources demanded by air pollution control requirements. The steps involved in producing the demand estimates for the decision-maker are illustrated in Figure 5-1. As shown, engineering-economic data and assumptions on sources of air pollution and air pollution control systems are the inputs to a control cost estimating procedure. The estimating procedure (which is described in detail in Section 5.2) varies for each industry according to the quality of the input data for that industry. Specifically, industries in which plants are identified and characterized individually have control costs developed on a plant-by-plant basis. On the other hand, in cases where only a number of plants in an industry can be identified (and not specific plant characteristics such as process size), model plants, which are selected to be representative of plants in the industry, must be determined from nationally available statistics. Control costs are then based on the model plant characteristics.

As indicated in Figure 5-1, this data bank of control costs is used to prepare the annual ECA Report to Congress. This same data bank is the basis for the "305(a) Approach" demand estimating technique. There are two steps involved in preparing the demand estimate. First, the data from the ECA Report data bank are structured by source category to identify the additional control systems and quality and quantity of fuel required for the control of emissions from each process. Also, data on the investment and annual control costs in addition to data on the quantity of controlled and uncontrolled particulate and sulfur dioxide emissions are identified on a process-by-process basis (where possible).

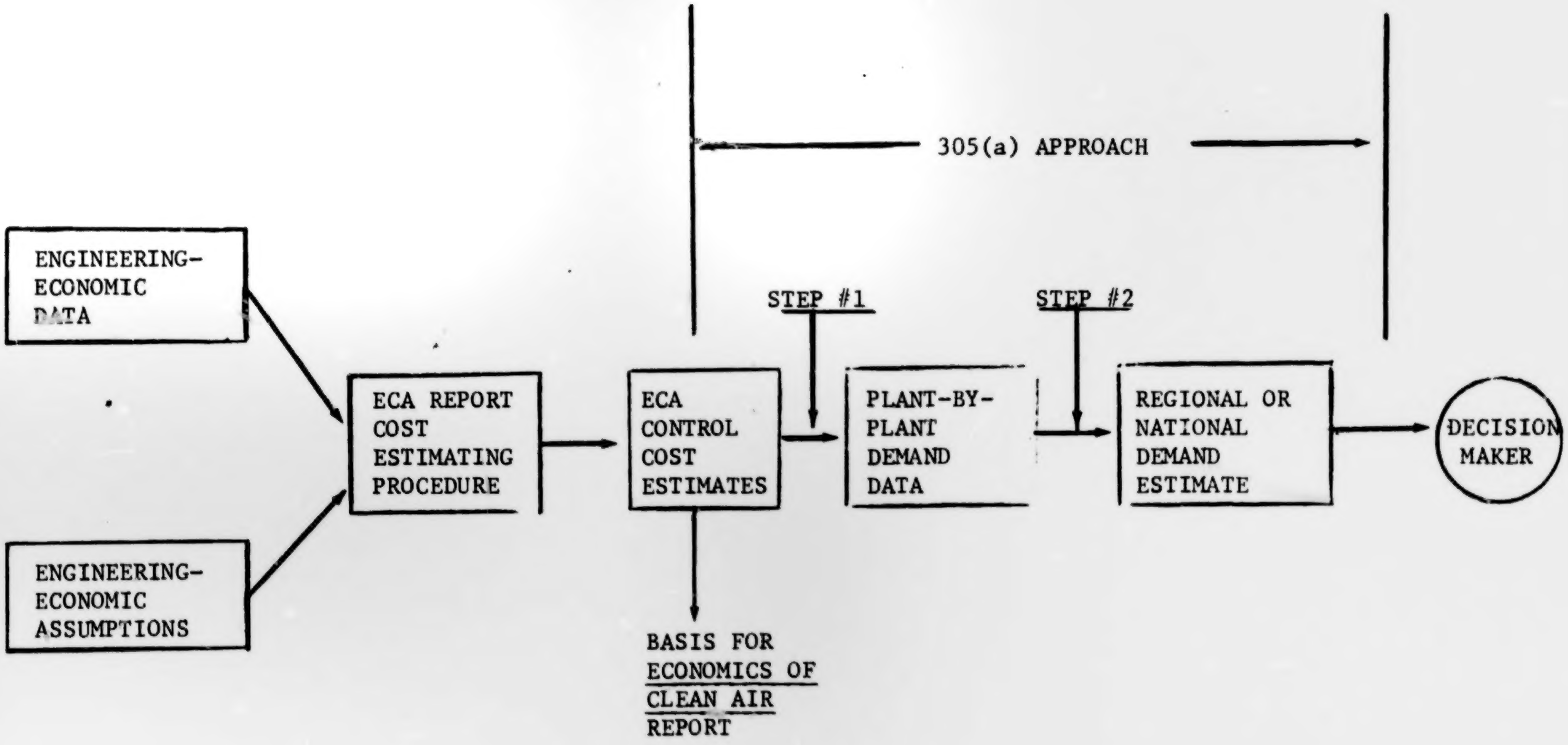

ENGINEERING-ECONOMIC DATA
ENGINEERING-ECONOMIC ASSUMPTIONS
ECA REPORT COST ESTIMATING PROCEDURE
ECA CONTROL COST ESTIMATES
BASIS FOR ECONOMICS OF CLEAN AIR REPORT
305(a) APPROACH
STEP #1
PLANT-BY-PLANT DEMAND DATA
STEP #2
REGIONAL OR NATIONAL DEMAND ESTIMATE
DECISION MAKER

FIGURE 5-1. PROCEDURE FOR DEVELOPING CONTROL MEASURE DEMAND ESTIMATES WITH THE 305(a) APPROACH

The second step of the 305(a) Approach requires an aggregation of the data at the regional or national level for demand estimation presentations.

The 305(a) Approach is a simple technique for converting the control cost data into useful regional and national control measure demand estimates. The procedure requires some engineering calculations which are needed to determine low-sulfur fuel-use estimates. No other engineering or economic analyses are required.

If the demand estimates which result from the 305(a) Approach are good approximations of the estimated demand, few resources will be required to develop the ECA Report data bank into useful demand estimates. The purpose of this report is to evaluate the reliability of the demand estimates and recommend whether or not this approach has merit. If it does, then another potential use for the ECA Report control cost data bank has been identified (see Figure 5-2).

To illustrate the 305(a) Approach, data from the third report to Congress (i.e., the March 1971 version) have been analyzed for four air quality control regions (AQCRs). By selecting the same AQCRs that were used in demonstrating the Aggregation and Extrapolation approaches, comparisons of the resulting demand estimates are made possible. The comparison of the three demand estimating techniques are presented in Section 1.0.

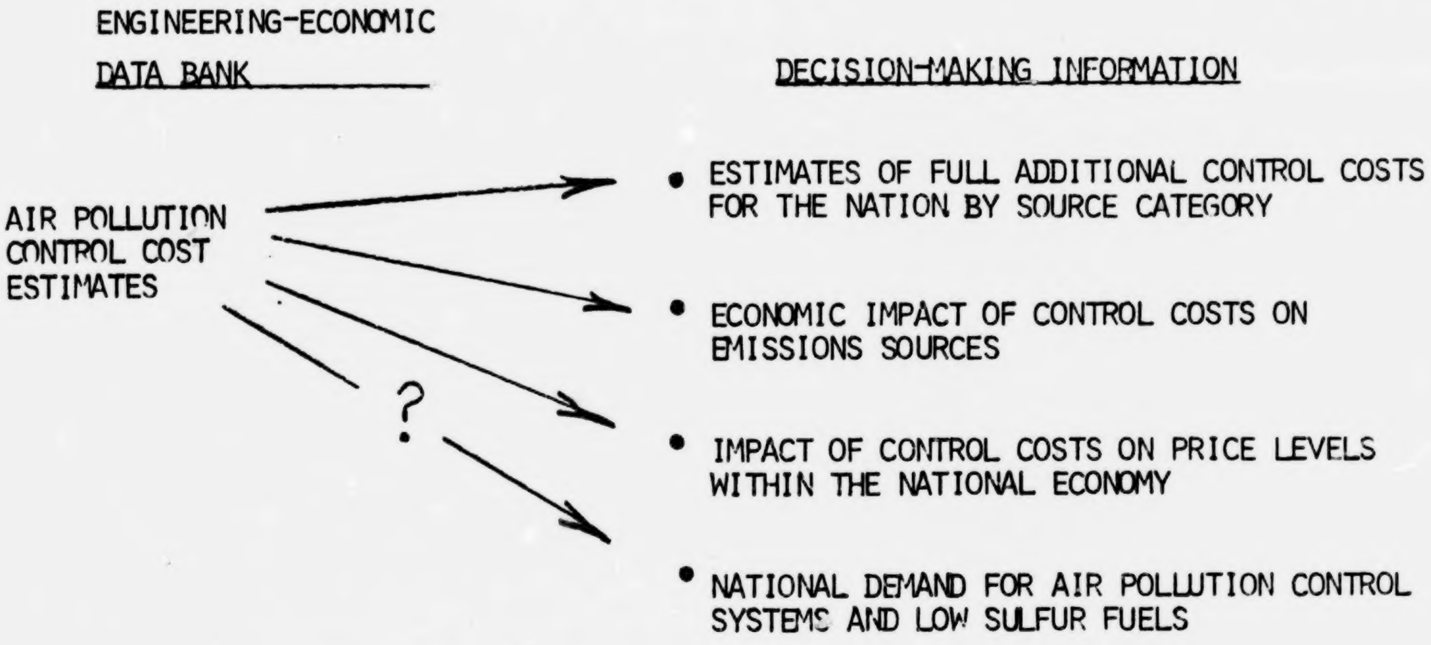
5.2 DESCRIPTION OF THE 305(a) APPROACH AND PRESENTATION OF REGIONAL DEMAND ESTIMATES.

5.2.1 Introduction

This section describes the two steps of the 305(a) Approach. Because the quality of the demand estimates produced by the 305(a) Approach is directly dependent upon the data and procedures used in developing the ECA Report control cost estimates, the ECA Report procedures will be reviewed also. In addition, estimates of control system and control costs on a plant-by-plant basis will be presented for four AQCRs. Finally, control measure demand estimates will be presented for each of the four AQCRs. No national demand estimate will be presented in this report although it is recognized that such as estimate is feasible. The national estimate can be determined by applying the 305(a) Approach to control cost estimates for the entire nation. At this time such an estimate is not possible since

FIGURE 5-2

THE DEVELOPMENT OF DECISION-MAKING INFORMATION FROM THE ECONOMICS OF CLEAN AIR CONTROL COST ESTIMATES



ENGINEERING-ECONOMIC DATA BANK

DECISION-MAKING INFORMATION

AIR POLLUTION CONTROL COST ESTIMATES

- ESTIMATES OF FULL ADDITIONAL CONTROL COSTS FOR THE NATION BY SOURCE CATEGORY
- ECONOMIC IMPACT OF CONTROL COSTS ON EMISSIONS SOURCES
- IMPACT OF CONTROL COSTS ON PRICE LEVELS WITHIN THE NATIONAL ECONOMY
- NATIONAL DEMAND FOR AIR POLLUTION CONTROL SYSTEMS AND LOW SULFUR FUELS

the 1971 ECA Report provides control cost estimates for sources in selected industries in only 298 of the nation's metropolitan areas. The 1972 ECA Report will comprehensively evaluate all sources in the nation which are part of the selected industries.

Before describing the steps of the 305(a) Approach and the resulting control measure demand estimates, the control cost estimating procedures of the ECA Report are reviewed. This provides the necessary background for a clear understanding of the two steps of the 305(a) Approach.

5.2.2 Scope of the Economics of Clean Air

The Economics of Clean Air is required by the Clean Air Act, as amended. The section of the Act which calls for the Report is as follows:

> Section 305. (a) In order to provide the basis for evaluating programs authorized by this Act and the development of new programs and to furnish the Congress with the information necessary for authorization of appropriations by fiscal years beginning after June 30, 1969, the Secretary, in cooperation with State, interstate, and local air pollution control agencies, shall make a detailed estimate of the cost of carrying out the provisions of this Act; a comprehensive study of the cost of program implementation by affected units of government; and a comprehensive study of the economic impact of air quality standards on the Nation's industries, communities, and other contributing sources of pollution, including an analysis of the national requirements for, and the cost of, controlling emissions to attain such standards of air quality as may be established pursuant to this Act or applicable State law. The Secretary shall submit such detailed estimates and the results of such comprehensive study of cost for the five-year period beginning July 1, 1969, and the results of such other studies, to the Congress not later than January 10, 1969, and shall submit a reevaluation of such estimate and studies annually thereafter.

To respond to this requirement, APCO has developed, over the past three years, control cost estimating procedures and a sizable engineering-economic data bank based on industrial statistics, national fuel-use estimates, research studies of air pollution control systems and costs, air pollution engineering factors, and numerous engineering assumptions.

Table 5-1 presents the pollutants which were studied in the 1971 ECA Report. The listed pollutants are those for which criteria and control technology documents have been or soon will be published. The source

TABLE 5-1

SCOPE OF 1971 ECONOMICS OF CLEAN AIR REPORT

POLLUTANTS

- PARTICULATES
- SULFUR DIOXIDE
- HYDROCARBONS
- CARBON MONOXIDE
- FLUORIDES
- LEAD

STATIONARY SOURCE CATEGORIES

- SOLID WASTE DISPOSAL
- COMMERCIAL-INSTITUTIONAL HEATING
- INDUSTRIAL BOILERS
- RESIDENTIAL HEATING
- STEAM-ELECTRIC POWER
- ASPHALT BATCHING
- BRICK AND TILE
- COAL CLEANING
- CEMENT
- ELEMENTAL PHOSPHORUS AND PHOSPHATE FERTILIZER
- GRAIN MILLING AND HANDLING
- GREY IRON FOUNDRIES
- IRON AND STEEL
- KRAFT PULP
- LIME
- PETROLEUM REFINING AND STORAGE
- PRIMARY AND SECONDARY NON-FERROUS METALLURGY
- RUBBER (TIRES)
- SULFURIC ACID
- VARNISH

categories listed are the stationary sources which are the major contributors of the identified pollutants.

The ECA Report evaluates the cost of controlling emissions from processes which are specifically affected by the emission control regulations required by the Clean Air Act. Not all processes--whether large or small, clean or dirty--are identified in the Report. Only specific processes in the selected industries (which covers nearly all of the identifiable stationary sources of emissions) are included in the analysis. This means that the ECA Report is not totally comprehensive and, yet, consequently, the control measure demand estimates of the 305(a) Approach will not be totally comprehensive.

Gas cleaning equipment is used for numerous purposes in our economy, that is, for purposes other than meeting emission control regulations required by the Clean Air Act. Thus, it is important to identify "air pollution control equipment" as used in this report. The terms "air pollution equipment" or "control measures" will be used to identify the gas cleaning equipment specifically demanded by the requirements of emission control regulations for the pollutants and processes identified in Table 5-1. A further discussion of this follows.

An "air pollution control system" is defined as equipment or fuel switching which is installed for the primary purpose of reducing air pollutant emissions to comply with emission standards. The term "gas-cleaning equipment" is used to describe all air pollution control systems as well as equipment used for other process purposes. Air pollution economics draw the fine line between what is and what is not an "air pollution control system." The distinction is based on the utility of the equipment as a profitable or "break-even" investment. If gas-cleaning equipment is used for cost-cutting (i.e., profitable) purposes (in addition to the goal of air pollution control) in a manufacturing process and the investment is recovered over the depreciable life of the equipment, then the gas-cleaning equipment is not considered an "air pollution control system."

When used to capture valuable material before entering the atmosphere, gas-cleaning equipment (which pays for itself over the normal life of the equipment) is considered "process equipment" rather than an air pollution control system (such as electrostatic precipitator on a basic oxygen furnace). Nor is gas-cleaning equipment considered an air pollution control system when it is used internally in a manufacturing process. Further, emission control systems which are justified on the basis of reduced plant maintenance (such as the avoidance of excess wear in bearings or the reduction in cost to clean the plant environment from emitted dust) are not defined as "air pollution control systems" (economists consider these costs internal to the firm. Air pollution, as defined here, is an externality. Emissions are controlled when receptors external to the firm are in need of protection).

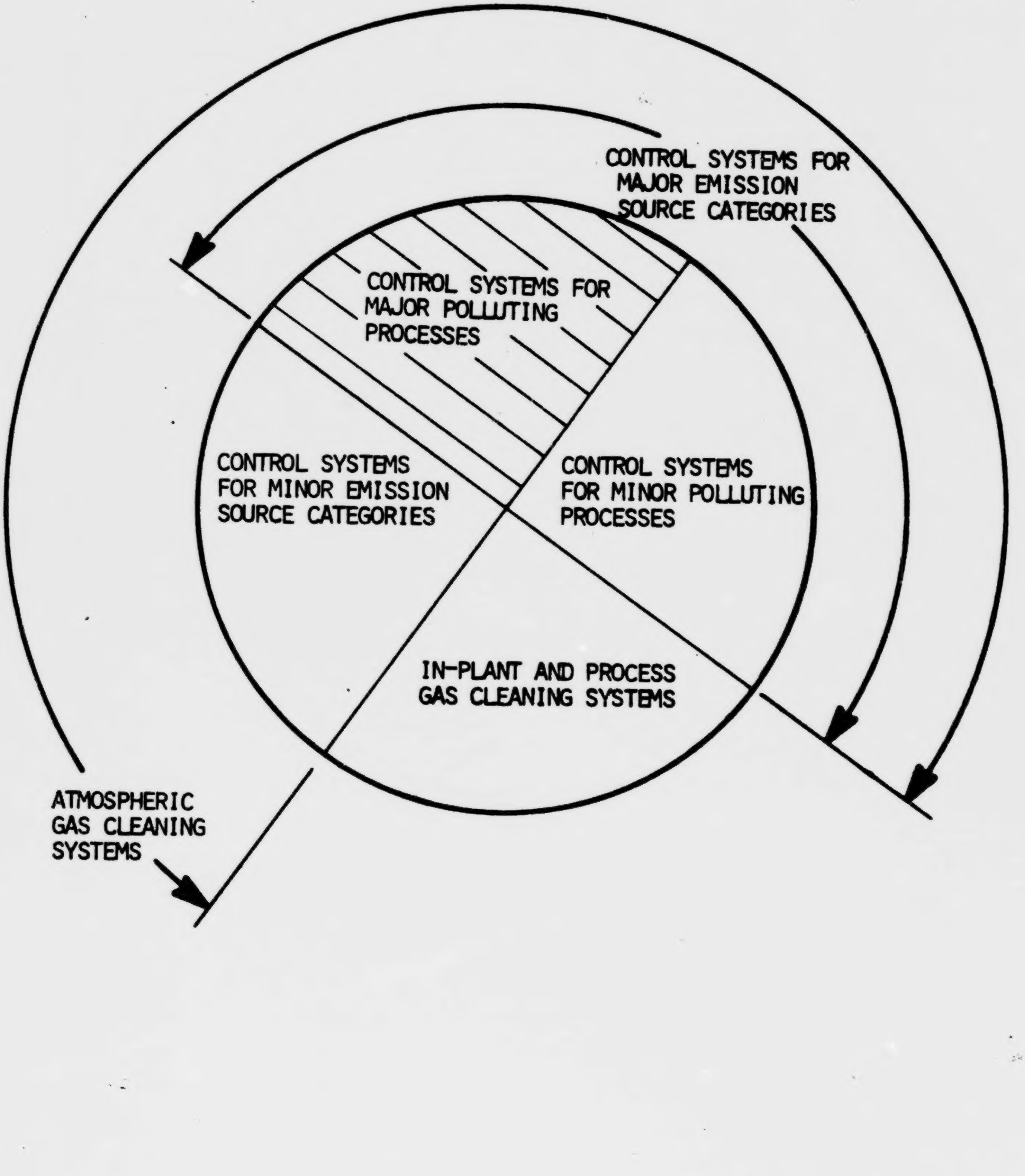
The ECA Report accounts for the entire emission control investment, including the cost of control hardware, auxiliary equipment, and installation, but does not generally include the cost of the pollutant disposal system. The incremental costs of low-sulfur fuels and of boiler conversions are also included as air pollution control costs.

It is also important to acknowledge that the ECA Report does not include other resources demanded by air pollution control legislation, i.e., the demand for surveillance instrumentation and staff, other control agency resources, and other equipment and manpower requirements of the private sector.

Figure 5-3 illustrates the sector of the gas-cleaning market that is analyzed in this study. As shown, the demand study examines the control systems needed to control emissions from the major polluting sources affected by emission standards (indicated by the shaded area. The relative size of the shaded area in no way indicates the relative size of the market for the resources. It is believed that the costs for the systems identified in the ECA Report are a sizable portion of the total gas cleaning market). In-plant and process gas-cleaning systems are not considered. Also, minor sources of atmospheric emissions (such as small lumber yards, construction and demolition activities, small fabricating plants, etc.) have not been analyzed. Finally, minor polluting processes or major industries which are generally controlled because of localized "plant nuisances" are not analyzed since, in general, these processes are not affected by air pollution control regulations but are controlled because of "good company practice."

FIGURE 5-3

THE SCOPE OF THE DEMAND STUDY


CONTROL SYSTEMS FOR MAJOR EMISSION SOURCE CATEGORIES
CONTROL SYSTEMS FOR MAJOR POLLUTING PROCESSES
CONTROL SYSTEMS FOR MINOR EMISSION SOURCE CATEGORIES
CONTROL SYSTEMS FOR MINOR POLLUTING PROCESSES
IN-PLANT AND PROCESS GAS CLEANING SYSTEMS
ATMOSPHERIC GAS CLEANING SYSTEMS

5.2.3 The Economics of Clean Air Control Cost Estimating Procedure

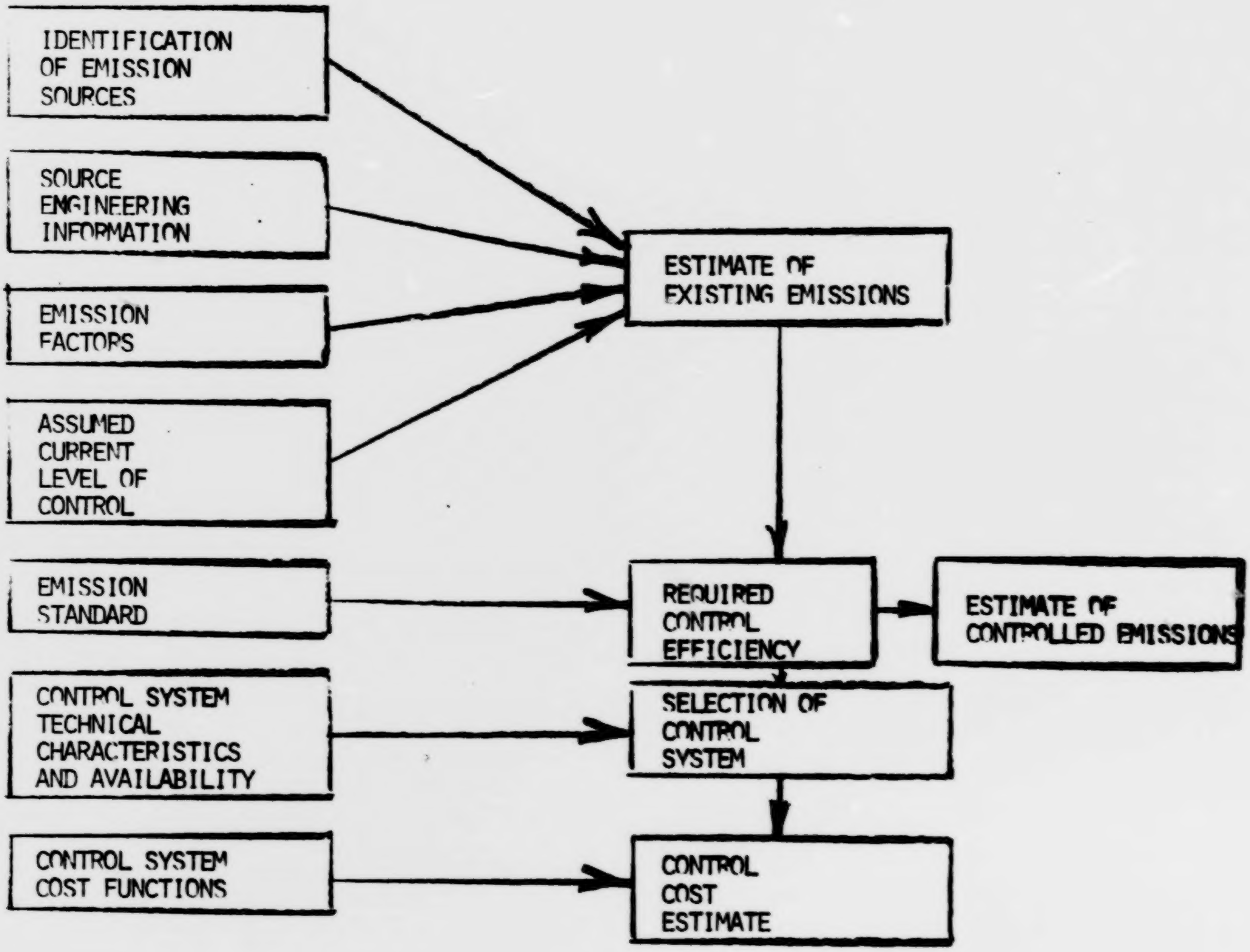
Procedures have been developed by APCO's Division of Economic Effects Research (DEER) for estimating control costs for source categories. The analytical procedures combine the best available engineering and cost data with assumptions as necessary to arrive at the desired control cost estimates. A general cost estimating procedure has been identified as the basis for the development of all control cost estimates. Because varying amounts of input data are available for each source category under study, modifications to the procedure have been created to compensate for data inadequacies. First, the general procedure is presented, followed by a description of the specific methods used for specific source categories. A flow chart which illustrates the general procedure is shown in Figure 5-4.

The data and assumptions which are inputs to the estimating procedure are listed along the left-hand side of the flow chart. A general description of each input category follows:

> Identification of Emission Sources - Data which identify all major and minor sources of specific pollutants in each selected source category.
>
> Source Engineering Information - Data on the type of process, process production rate or capacity, type and quantity of fuel burned, and other source characteristics.
>
> Emission Factors - Engineering factors which relate the potential rate of process emissions to process size.
>
> Assumed Current Level of Control - Data or assumptions on the current emission control practices of a source or source category.
>
> Emissions Standard - An emission control regulation for each process category assumed adequately stringent to comply with commonly accepted air quality standards.
>
> Control System Technical Characteristics and Availability - Data on the alternative control systems for a given source including the

FIGURE 5-4

CONTROL COST ESTIMATING PROCEDURE IN THE COST OF CLEAN AIR REPORT


IDENTIFICATION OF EMISSION SOURCES
SOURCE ENGINEERING INFORMATION
EMISSION FACTORS
ASSUMED CURRENT LEVEL OF CONTROL
EMISSION STANDARD
CONTROL SYSTEM TECHNICAL CHARACTERISTICS AND AVAILABILITY
CONTROL SYSTEM COST FUNCTIONS
ESTIMATE OF EXISTING EMISSIONS
REQUIRED CONTROL EFFICIENCY
ESTIMATE OF CONTROLLED EMISSIONS
SELECTION OF CONTROL SYSTEM
CONTROL COST ESTIMATE

effectiveness of emission control and the availability of the system or fuel for solving the control problem.

Control System Cost Functions - Engineering and cost data which relate the cost of emission control to the capacity or production rate of a given source type.

The top four input categories in Figure 5-4 are required to determine an estimate of the existing emissions from sources within a source category. The emission standard determines the level of control efficiency required to obtain a desirable air quality. A selection of the most desirable control system (for the purpose of control cost estimates) is made following an examination of the technical characteristics of alternative control systems, their availability, current industrial practices, and other engineering assumptions. Finally, a control system cost function for the selected control alternative is used to determine the control cost estimate.

As previously indicated, the statistics for identifying emission sources and the descriptive data for such sources differ considerably for the industries studied. Inconsistencies in the quality of input data require modifications to the basic cost-estimating procedure. Thus alternative estimating methods have been developed to cope with the problem of data inconsistencies among industries.

For convenience in identifying the different methods, the following terminology will be used:

Method	Situation
I	For multi-process plants where process capacities are known.
II	For single-process plants where the plant capacity is known.
III A	A "model plant" is used for a multi-process plant (individual plant capacities not known).
III B	A "model plant" is used for a single-process plant (individual plant capacities not known).

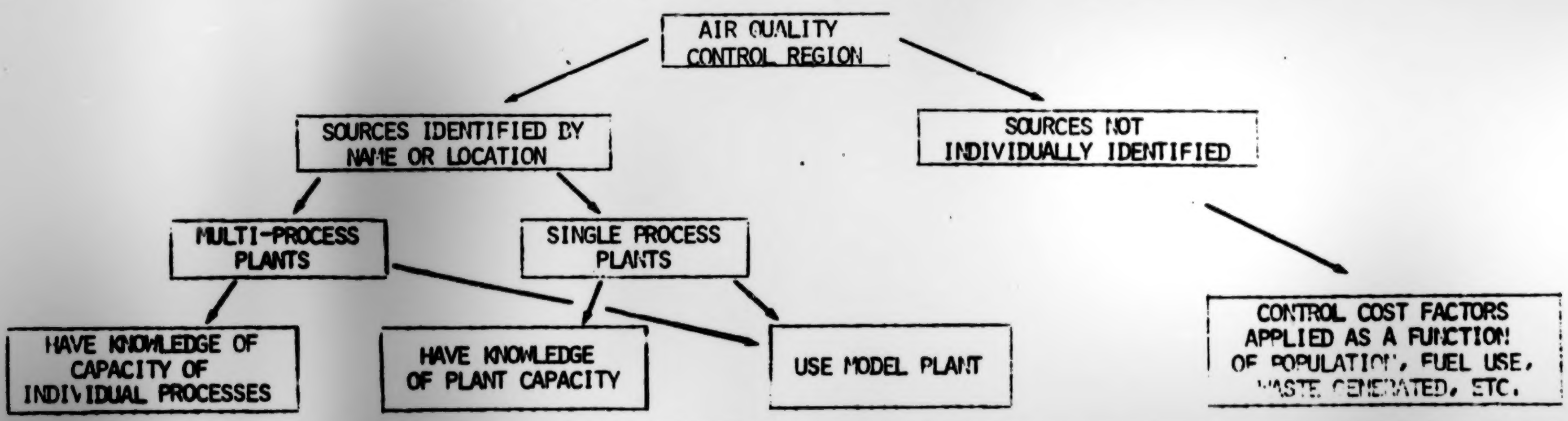
Method	Situation
IV	Gross regional characteristics are used as a basis for estimation.

Figure 5-5 facilitates a better understanding of the specific methods. As shown, air quality control regions contain some sources which have been identified by name and/or location. Regions also contain sources which have not been identified individually. In general, data are available for industrial processes as well as steam-electric powerplants and municipal incinerators. Domestic and commercial solid waste disposal units as well as other stationary combustion sources (i.e., excluding powerplants) are not generally identified on a source-by-source basis.

In general, the two types of sources which are identified by name and location are (1) plants which have only one major process type which is susceptible to emission control regulations, and (2) plants which have more than one process. For a single process plant, there may or may not be source engineering information on plant capacity. When such information is available, control cost estimates are determined by the direct application of a control cost function to the known plant capacity (Method II). When plant capacities for an industry are not known, a model plant is determined through engineering analysis. The model plant is representative of the "typical" plant found in the industry. The assumption is made that each plant within the industry has the characteristics of the model plant and control cost estimates are based on that assumption (Method III B).

For some industries with multi-process plants, statistics are available on the capacity of each polluting process. In that case, control cost functions for these processes are directly applied (as a function of the known process capacity) to determine control cost estimates (Method I). When process capacities are not known for multi-process plants, a model plant is determined. The model plant characteristics are consistent with the plant design most commonly found within the industry. Control cost estimates for such plants are based on the assumed mix of processes (Method III A).

FIGURE 5-5 DETAILED VIEW OF ECA COST ESTIMATING PROCEDURE


AIR QUALITY CONTROL REGION
SOURCES IDENTIFIED BY NAME OR LOCATION
SOURCES NOT INDIVIDUALLY IDENTIFIED
MULTI-PROCESS PLANTS
SINGLE PROCESS PLANTS
HAVE KNOWLEDGE OF CAPACITY OF INDIVIDUAL PROCESSES
HAVE KNOWLEDGE OF PLANT CAPACITY
USE MODEL PLANT
CONTROL COST FACTORS APPLIED AS A FUNCTION OF POPULATION, FUEL USE, WASTE GENERATED, ETC.

METHOD I	METHOD II	METHOD III A & B	METHOD IV
INPUT DATA AND RESULTING ESTIMATES			

• COMPANY
• TYPE PROCESS
• PROCESS CAPACITY
• ASSUMED OR KNOWN CONTROLS (TYPE AND EFF.)
• ANNUAL PART. AND SO_X EMISSIONS (CONT. AND UNCONT.)
• CONTROL INVESTMENT($)
• ANNUAL CONTROL COST($)
• CONTROL SYSTEM (TYPE AND EFF.)
• TYPE CONTROL REGULATION ASSUMED
	• COMPANY OR NUMBER OF PLANTS
	• TYPE PROCESS
	• MODEL PLANT CAPACITY
	• ASSUMED CONTROLS (TYPE AND EFF.)
	• ANNUAL PART. AND SO_X EMISSIONS (CONT. AND UNCONT.)
	• CONTROL INVESTMENT($)
	• ANNUAL CONTROL COST($)
	• CONTROL SYSTEM (TYPE AND EFF.)
	• TYPE CONTROL REGULATION ASSUMED
		• COMPANY
		• TYPE PROCESS
		• PLANT CAPACITY
		• ASSUMED OR KNOWN CONTROLS (TYPE AND EFF.)
		• ANNUAL PART. AND SO_X EMISSIONS (CONT. AND UNCONT.)
		• CONTROL INVESTMENT($)
		• ANNUAL CONTROL COST($)
		• CONTROL SYSTEM (TYPE AND EFF.)
		• TYPE CONTROL REGULATION ASSUMED
			• POPULATION DATA
			• QUANTITY OF SW GENERATED
			• CONTROL SYSTEM (TYPE AND EFF.)
			• CONTROL INVESTMENT($)
			• ANNUAL CONTROL COST($) ANNUAL PART. AND SO_X (CONT. AND UNCONT.)
			• NUMBER OF BOILERS:
			  • RESIDENTIAL HEATING
			  • COMM. AND INSTIT.
			  • INDUSTRIAL, AND
			• QUANTITY OF FUELS BURNED
			  • COAL (S CONTENT)
			  • OIL (S CONTENT)
			  • NG
			• CONVERSION COSTS
			• TYPE & QUANTITY OF FUEL SWITCH

SOURCE CATEGORIES			

• IRON AND STEEL
• PETROL. REFINING
	• MUNICIPAL INCINERATORS
	• STEAM-ELECTRIC POWER
	• PRIMARY NONFERROUS SMELTERS
	• SULFURIC ACID
	• PHOSPHATE FERTILIZER(PARTIAL)
	• CEMENT
	• GREY IRON FOUNDRIES
		• COAL CLEANING
		• GRAIN MILLING
		• GRAIN HANDLING
		• PHOSPHATE FERTILIZER(PARTIAL
		• ASPHALT BATCHING
		• LIME
		• SECONDARY NONFERROUS METAL
			• OTHER SOLID WASTE DISPOSAL
			• OTHER STATIONARY COMBUSTION
			  ○ INDUSTRIAL BOILERS
			  • COMMERCIAL-INSTITUTIONAL HEATING PLANTS
			  ○ RESIDENTIAL HEATING PLANTS

When the identification of individual sources is not economically justified for analytical purposes, regional characteristics, such as population, fuel use, or quantity of solid waste generated, are used in still another control-cost-estimating procedure. No sources are treated individually. Here, the emission contribution from each source alone is small even though the emission from the total aggregate of sources may be substantial. Cost factors are applied to the regional characteristics to determine the cost of control (Method IV).

The detailed cost and engineering factors utilized in the five methods are not reported in the ECA Report. The relevant data and assumptions are presented in the back-up report to the 1970 Cost of Clean Air Report (Reference 4). The 1971 Report is also supported by a technical back-up document (Reference 9).

5.2.4 305(a) Approach - Step #1

The procedures described in the previous section have been used to develop the DEER control cost data bank. The first step in the 305(a) Approach uses this data and structures it by source category according to a desired format. The following data elements have been aggregated for this report:

Air quality control region
Company or plant name
Process description
- type
- capacity
- number of units

Required controls
- type of system
- system efficiency
- alternative fuel

- fuel type
- fuel quantity

Particulate and sulfur dioxide emission data
  - existing quantity of emissions
  - controlled quantity of emissions

Full additional control costs
  - investment
  - annual cost

This information is considered essential to characterize the resources that will be demanded as a result of the emission control regulations

The data for stationary source control of particulates and sulfur dioxide emissions are presented for four AQCRs in Table 5-2 through 5-5. The following source categories have been identified:

Solid waste disposal
Steam-electric power generating
Other fuel combustion sources
Industrial processes.

Footnotes at the base of each table indicate the specific cost-estimating procedure utilized in the determination of the control cost and emission estimates.

Notice that the following source categories can serve as examples where the cost estimating methods described in the previous section have been applied:

Method	Example Source Category
I	Petroleum Refining
II	Sulfuric Acid
III A	Coal Cleaning
III B	Asphalt Batching
IV	Other Fuel Combustion Sources

Also identified in some of the tables are descriptions of the type and efficiency of the control systems assumed to be currently on each source. The assumptions are required for calculating the quantity of existing emissions as well as in determining the adequacy of the existing

Table 5-2. SOLID WASTE DISPOSAL

AQCR	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL (1) CONTROL COST		PARTICULATE EMISSIONS (TONS/YR.)	
	TYPE	CAPACITY (TON/DAY)	YEAR BUILT	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	(2) EXISTING	CONTROLLED
Cinti	Municipal	100	1929	Wet Scrubber	85	50	36	63.8	38.2
	"	50	1930	"	85	25	18	31.9	19.1
	"	50	1930	"	85	25	18	31.9	19.1
	"	200	1931	"	85	100	72	127.6	76.4
	"	180	1931	"	85	90	65	114.8	68.8
	"	50	1934	"	85	25	18	31.9	19.1
	"	300	1935	"	85	150	108	191.4	114.6
	"	19	1937	"	85	10	7	121.2	7.3
	"	50	1949	"	85	25	18	31.9	19.1
	"	500	1954	"	90	250	180	319.0	127.5
	"	60	1957	"	85	30	22	38.3	23.0
	"	150	1960	"	85	75	54	95.7	47.3
	"	300	1962	"	85	120	99	191.4	114.6
	"	500	1965	"	90	100	155	319.0	127.5
	"	150	1965	"	85	30	47	95.7	47.3
	"	120		"	85	24	37	76.6	45.9
	Dom. & Comm.(3)			"	85-95	1,542	683	14,813.0	1,899.0
Wash.	Municipal	125	1932	Wet Scrubber	85	63	45	79.8	47.7
	"	425	1932	"	87.5	213	153	271.2	134.2
	"	300	1949	"	85	150	108	191.4	114.6
	"	500	1955	"	90	250	180	319.0	127.5
	"	750	1957	"	95	375	270	478.5	95.5
	"	500	1961	"	90	200	165	319.0	127.5
	"	1,050	1965	"	95	210	325	669.9	134.0
	"	300	1967	"	85	60	43	191.4	114.6
	Dom. & Comm.(3)	-	-	"	85-95	4,039	1,831	33,791.0	3,584.0

(1) Control costs for municipal incinerators based on known capacity and "year built."

(2) Assumed existing incinerators controlled by inertial separator (75% efficient).

(3) Domestic and commercial category includes costs and emissions of new incinerators required for disposal of some uncollected and collected (but currently open burned) wastes in addition to all small-scale incinerators and auto body disposal operations.

Table 5-2. SOLID WASTE DISPOSAL

AQCR	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST (1)		PARTICULATE EMISSIONS (TONS/YR.)	
	TYPE	CAPACITY (TON/DAY)	YEAR BUILT	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING(2)	CONTROLLED
St. Louis	Municipal	500	1950	Wet Scrubber	90	250	180	319.0	127.5
	"	500	1958	"	90	250	180	319.0	127.5
	Dom. & Comm.(3)			"	85-95	1,739	1,094	22,340.0	1,968.0
Phila.	Municipal	40	1920	"	85	20	14	25.5	15.3
	"	25	1927	"	85	13	9	16.0	9.5
	"	97	1938	"	85	49	35	61.9	37.1
	"	200	1950	"	85	100	72	127.6	76.4
	"	300	1950	"	85	150	108	191.4	114.6
	"	600	1951	"	90	300	216	382.8	153.0
	"	100	1954	"	85	50	36	63.8	38.2
	"	50	1954	"	85	25	18	31.9	19.1
	"	450	1955	"	90	225	162	287.1	115.0
	"	200	1955	"	85	100	72	127.5	76.4
	"	200	1955	"	85	100	72	127.6	76.4
	"	600	1956	"	90	300	216	382.8	153.0
	"	100	1958	"	85	50	36	63.8	38.2
	"	300	1959	"	85	150	108	191.4	114.6
	"	600	1960	"	90	300	216	382.8	153.0
	"	300	1961	"	85	120	99	191.4	114.6
	"	500	1961	"	90	200	165	319.0	127.5
	"	500	1961	"	90	200	165	319.0	127.5
	"	500	1962	"	90	200	165	319.0	127.5
	"	300	1962	"	85	120	99	191.4	114.6
	"	300	1964	"	85	120	99	191.4	114.6
	"	250	1965	"	85	50	78	159.5	95.5
	"	600	1965	"	90	120	186	382.8	153.0
	Dom. & Comm.(3)	---	--	"	85-95	7,984	3,200	53,855.0	5,790.0

See Page 1 of 2 for footnotes (1), (2) and (3).

Table 5-3. STEAM-ELECTRIC POWER

AOCR	Plant	Capacity (Megawatts)	Fuel Sulfur Content		Additional Controls Required	Emission Data (Ton/Yr.) (1)(2)				Incremental Control Cost	
						Particulates		Sulfur Dioxide			
			Coal (%)	Oil (%)		Existing	Required	Existing	Required	Investment ($1000)	Annual ($1000/Yr.)
Cinti.	W.C. Beckjord	760.5	1.50	1.36	Wet Limestone Scrubbing	17,275	1,233	48,034	4,803	7,490 (3)	2,410 (3)
	West End	219.3	1.50	--	"	1,287	92	3,578	358	2,518	504
	Tanners Creek	1,098.0	2.80	1.70	"	8,656	261	111,313	11,131	11,479	3,700
	Miami Fort	--	1.50	1.36	"	7,562	540	21,027	2,102	5,650	1,801
Wash.	Benning Road	263.8	1.50	1.36	"	3,871	277	13,381	1,338	6,394	1,669
	Buzzard Point	270.0	1.50	1.36	"	1,814	130	6,258	626	3,938	770
	Possum Point	491.0	1.00	--	"	7,208	514	17,814	4,454	6,303	1,217
	Potomac River	--	1.50	0.50	"	8,148	582	30,212	3,024	5,944	1,772
	Dickerson	--	1.80	2.17	"	744	53	2,888	289	5,784	349
	Chalk Point	--	1.80	2.17	"	10	1	372	37	6,907	303
St. Louis	Wood River	650.1	3.30	1.70	"	14,178	1,013	84,797	8,480	7,504	2,516
	Cahokia	300.0	3.27	1.70	"	1,087	1,087	6,455	1,971	0	100
	Venice #2	500.0	3.27	0.00	"	6,678	476	39,577	3,958	6,111	1,666
	Meramec	800.0	2.68	1.70	"	21,665	1,547	102,947	10,295	10,189	3,191
	Ashley	--	2.68	1.70	"	190	190	903	337	0	15
Phila.	Edgemoor	389.8	2.75	1.48	"	7,233	517	42,138	4,214	4,725	1,473
	Chester	256.0	2.17	2.75	"	506	36	3,912	391	3,004	855
	Cromby	417.5	2.17	2.75	"	6,796	485	27,973	2,797	4,289	1,307
	Delaware	499.3	2.17	2.75	"	7,302	522	31,058	3,106	6,168	1,869
	Eddystone	707.2	2.17	2.75	"	13,911	994	57,257	5,726	6,822	2,112
	Richmond	474.8	2.17	2.75	"	5,316	380	24,734	2,473	6,558	2,030
	Schuylkill	325.4	2.17	2.75	"	9,030	645	37,166	3,717	4,951	1,523
	Southwark	345.0	2.17	2.75	"	10,939	781	45,022	4,502	5,424	1,656
	Deepwater	--	2.75	2.50	"	4,049	289	24,983	2,498	5,192	1,838
	Burlington	--	3.00	2.75	"	178	13	5,610	561	5,993	1,883
	Barbadoes	--	2.17	2.75	"	2,189	2,189	9,219	4,162	0	311
	Delaware City	--	0.00	1.48	"	13	13	332	51	0	338

(1) Particulate emission approximately 80% controlled for all sources.
(2) Sulfur oxides are essentially uncontrolled.
(3) Control cost estimates based on individual power plant capacity.

Table 5-4. OTHER FUEL COMBUSTION SOURCES

			EXISTING FUEL COMBUSTION					REQUIRED FUEL CONSUMPTION			EMISSION DATA				FULL ADDITIONAL CONTROL COST (4)	
			NAT. GAS	COAL		OIL		NAT. GAS	OIL		PARTICULATES		SULFUR DIOXIDE			
	COMBUSTION UNITS		QUANTITY	QUANTITY	SULPHUR	QUANTITY	SULPHUR	QUANTITY	QUANTITY	SULPHUR	EXISTING	REQUIRED	EXISTING	REQUIRED	INVESTMENT	ANNUAL
AQCR	TYPE	NUMBER	(10^6cf.)	(10^3tons)	CONTENT (%)	(10^6gal.)	CONTENT (%)	(10^6cf.)	10^6gal.)	CONTENT(%)	(TONS)	(TONS)	(TONS)	(TONS)	($1000)	($1000)
Cinti.	**Industrial**	1,670	0	840 (1)	2.0	15	1.75	0	138	1.0	37,100	1,600	33,600	12,200	8,826	7,962
	Comm. & Inst.	7,733	16,755	65.3(2)	1.0	30.9	.8	310	9	0.2-0.75	854	264	3,100	2,280	726	- 410
	Residential	485,383	34,288	267.8(2)	1.1	67.8	.5	4,980	9	0.2-0.5	2,936	420	8,600	3,000	(3)	(3)
Wash.	**Industrial**	704	0	Neg.	---	Neg.	1.75	0	0	1.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
	Comm. & Inst.	13,419	8,677	50.0(2)	1.6	190.2	.8	5	580	0.2-0.75	1,975	1,309	13,030	11,090	671	1
	Residential	800,034	28,436	484.6(2)	0.6	197.2	.5	29	4,620	0.2-0.5	5,410	910	12,600	9,000	(3)	(3)
St. Louis	Industrial	3,213	0	2,050 (1)	3.5	111	1.75	0	337	1.0	87,600	9,800	145,000	40,000	8,894	16,052
	Comm. & Inst.	11,348	22,604	0.0(2)		49.3	.8	0	0	0.2-0.75	334	334	2,820	2,820		
	Residential	708,200	36,789	646.4(2)	1.0	100.9	.5	10,410	26	0.2-0.5	6,990	665	18,800	5,050	(3)	(3)
Phila.	Industrial	10,127	0	3,700 (1)	2.5	911	1.75	0	608	1.0	174,000	15,800	300,000	122,000	15,609	10,445
	Comm. & Inst.	29,768	44,367	124.0(2)	1.8	340.8	.8	1,960	7	0.2-0.75	3,540	2,350	23,930	20,200	1,426	38
	Residential	1,529,512	63,630	459.4(2)	0.6	758.2	.5	3,950	43	0.2-0.5	8,710	4,400	35,050	31,000	(3)	(3)

(1) Ash content = 8%.

(2) Emission factor for particulates = 20#/ton of coal.

(3) The transition from residential burning of coal to oil, natural gas and electricity is not directly a result of concern over air pollution. No control costs have been allocated for the switch from coal to other fuel because of the long observed trend away from coal.

(4) Control costs based on incremental fuel prices and boiler conversion for estimated number of boilers and known fuel use.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: IRON AND STEEL

INDUSTRY CODE: 06

PAGE 2 OF 3

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL (3) CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Melt)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (4)	REQUIRED	EXISTING	REQUIRED
Phila.	U. S. Steel	Open Hearth	395	9	40" w.g. Venturi	96.4	16,517	6,656	12,917	619	(2)	(2)
"	"	Sintering	6,000.0(1)		20" w.g. Venturi	98.9	2,879	2,551	20,279	344	(2)	(2)
"	Luken Steel	Open Hearth	145	6	50" w.g. Venturi	92.3	4,748	2,167	5,852	914	(2)	(2)
"	"	Electric	145	1	H.T. Fabric Filter	92.0						
"	"	"	100	2	"	89.0						
"	Phoenix Steel	Open Hearth	150	5	40" w.g. Venturi	92.3	4,693	1,947	3,797	386	(2)	(2)
"	Allanwood St.	"	140	9	"	92.3						
"	"	Electric	18	1	H.T. Fabric Filter	84.0	5,694	2,367	4,578	476	(2)	(2)
"	"	Electric	45	1	"	87.0						
"	"	"	40	1	"	87.0						
"	"	"	11	1		84.0						
"	"	"	23	1	"	84.0						
"	"	Sintering	2,000.0(1)		20" w.g. Venturi	97.0	1,204	968	6,759	300	(2)	(2)

See Page 1 of 3 for footnotes (1), (2), (3) and (4).

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: IRON AND STEEL

INDUSTRY CODE: 06

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		PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL (3) CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
AQCR	COMPANY	TYPE	CAPACITY (Ton/Melt)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (4)	REQUIRED	EXISTING	REQUIRED
Phila.	Midvale-Heppenstall	Electric	30	1	H.T. Fabric Filter	87.0	596	388	1,521	455	(2)	(2)
"	"	"	50	1	"	87.0						
"	"	"	100	1	"	89.0						
"	"	"	25	1	"	84.0						
"	"	"	5	2	"	84.0						
"	Phoenix Steel	"	150	6	"	92.0	3,396	1,396	2,725	277	(2)	(2)
"	"	"	145	1	"	92.0						

See Page 1 of 3 for footnotes (1), (2), (3) and (4).

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: IRON AND STEEL

INDUSTRY CODE: 06

PAGE 1 OF 3

		PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL (3) CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
AQCR	COMPANY	TYPE	CAPACITY (Ton/Melt)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (4)	REQUIRED	EXISTING	REQUIRED
Cinti.	Interlake Steel	Open Hearth	78	2	40" w.g. Venturi	90.0	3,492	1,575	4,084	740	(2)	(2)
"	"	"	97	5	"	90.0						
"	"	Electric	75	3	H.T. Fabric Filters	89.0						
"	Armco Steel	Open Hearth	180	3	40" w.g. Venturi	94.0	5,060	2,086	4,033	346	(2)	(2)
"	"	"	190	3	"	94.0						
"	"	"	300	6	"	95.6						
"	Am. Compressed Steel	Electric	6	1	H.T. Fabric Filter	84.0	33	22	46	21	(2)	(2)
St. Louis	Granite City	Electric	250	2	H.T. Fabric Filter	95.0	12,138	4,892	9,447	459	(2)	(2)
"	"	"	300	2	"	95.0						
"	"	"	400	1	"	95.0						
"	"	"	500	1	"	95.0						
"	"	"	600	1	"	95.0						
"	"	Sintering	3,238.6 (1)		20" w.g. Venturi	98.0	1,785	1,503	10,947	308	(2)	(2)

(1) Capacity for sintering reported in tons per day.
(2) Sulfur dioxide emissions considered negligible relative to applicable emissions standards.
(3) Control cost estimates based on known capacity of processes.
(4) All basic oxygen furnaces assumed controlled to 95%; also, the following were assumed:

Process	Total Production Controlled (%)	Average Control Efficiency (%)
Open Hearth	27	90
Electric	61	90
Sintering (windbox)	90	75
Sintering (discharge)	0	0

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GREY IRON FOUNDRY

INDUSTRY CODE: 07

PAGE 1 OF 5

		PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
AQCR	COMPANY	TYPE	CAPACITY (Ton/Hr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
Cinti.	Star Foundry	Cupola	(1)	(1)	16-35" w.g. Venturi Scrubbers	85-95%	48	14	30	0.3	Neg.	Neg.
"	Klaene Foundry	"	"	"	"	"	62	18	35.9	4.1	"	"
"	Independence Foundry	"	"	"	"	"	48	14	3.0	0.3	"	"
"	Reliance Fdy.	"	"	"	"	"	75	22	67.9	7.7	"	"
"	Chris Erhart Foundry	"	"	"	"	"	73	22	62.8	7.1	"	"
"	Cinti. Milling	"	"	"	"	"	120	36	221.1	61.4	"	"
"	Standard Castings	"	"	"	"	"	68	20	51.1	5.8	"	"
"	Buckeye Fdy.	"	"	"	"	"	105	31	135.2	15.4	"	"
"	Oberhelman - Ritter	"	"	"	"	"	103	31	127.7	14.5	"	"
"	Tri-State Fdy.	"	"	"	"	"	91	27	84.5	9.6	"	"
"	Black Clawson (1)	"	"	"	"	"	126	38	209.3	23.8	"	"
"	H.P. Deuscher	"	"	"	"	"	95	29	99.5	11.3	"	"

(1) Capacity per plant not known; cost and emission estimates based on known "value of shipments" and "number of cupolas" for each plant.
(2) Assumed industry-wide average particulate removal efficiency of 12%.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GREY IRON FOUNDRY

INDUSTRY CODE: 07

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AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Hr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
Cinti.	Hamilton Fdy.	Cupola	(1)	(1)	16-35" w.g. Venturi Scrubbers	85-95%	320	96	421.0	51.3	Neg.	Neg.
"	Campbell-Hausfeld	"	"	"	"	"	99	30	128.2	14.6	"	"
"	Black - Clawson (2)	"	"	"	"	"	92	28	111.5	12.7	"	"
St. Louis	Spuck Iron and Foundry	"	"	"	16-35" w.g. Venturi Scrubbers	85-95%	63	19	38.7	4.4	"	"
"	Laclede Stoker	"	"	"	"	"	90	27	106.4	12.1	"	"
"	Banner Iron Works (1)	"	"	"	"	"	0	0	19.2	19.2	"	"
"	Liberty Fdy.	"	"	"	"	"	0	0	18.4	18.4	"	"
"	Didion & Sons	"	"	"	"	"	70	21	54.1	6.1	"	"
"	Banner Iron Works (2)	"	"	"	"	"	0	0	19.2	19.2	"	"
"	ABEX	"	[illegible]	"	"	"	82	25	84.5	9.6	"	"

See Page 1 of 5 for footnotes (1) and (2)

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GREY IRON FOUNDRY

INDUSTRY CODE: 07

PAGE 4 OF 5

		PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
AQCR	COMPANY	TYPE	CAPACITY (Ton/Hr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
Phila.	Bonair Fdy.	Cupola	(1)	(1)	16-35" w.g. Venturi Scrubber	85-95%	64	19	40.7	4.6	Neg.	Neg.
"	Schneider Bowman	"	"	"	"	"	81	24	82.0	9.3	"	"
"	Glode Enterprises	"	"	"	"	"	70	21	10.9	1.2	"	"
"	H.G. Enderlein	"	"	"	"	"	72	22	59.3	6.7	"	"
"	Perserverance Iron	"	"	"	"	"	55	16	17.7	2.0	"	"
"	Pottstown Mach.	"	"	"	"	"	58	17	24.7	2.1	"	"
"	March Brownback	"	"	"	"	"	75	23	67.6	7.7	"	"
"	Keystone Grey Iron Foundry	"	"	"	"	"	64	19	39.9	4.5	"	"
"	Buffalo Pipe & Foundry	"	"	"	"	"	88	26	101.4	11.5	"	"
"	Royersford Fdy.	"	"	"	"	"	62	19	34.7	3.9	"	"
"	Richmond Ring	"	"	"	"	"	40	14	1.0	0.1	"	"

See Page 1 of 5 for footnotes (1) and (2)

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GREY IRON FOUNDRY

INDUSTRY CODE: 07

PAGE 5 OF 5

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Hr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
Phila.	Spring City Foundry	Cupola	(1)	(1)	16-35" w.g. Venturi Scrubber	85-95%	63	19	36.5	4.1	Neg.	Neg.
"	Stanley G Flagg	"	"	"	"	"	181	55	405.1	46.1	"	"
"	ABEX	"	"	"	"	"	91	27	107.5	12.2	"	"

See Page 1 of 5 for footnotes (1) and (2)

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GREY IRON FOUNDRY

INDUSTRY CODE: 07

PAGE 3 OF 5

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Hr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
St. Louis	Excelsior Fdy.	Cupola	(1)	(1)	16-35" w.g. Venturi Scrubber	85-95%	68	21	50.7	5.8	Neg.	Neg.
"	Buckler Fdy.	"	"	"	"	"	53	16	12.6	1.4	"	"
"	East St. Louis Castings	"	"	"	"	"	138	42	250.5	28.5	"	"
"	Modern Fdy. & Mfg.	"	"	"	"	"	67	20	47.3	5.4	"	"
"	Autocrat	"	"	"	"	"	67	20	47.0	5.3	"	"
Phila.	Burlington	"	"	"	16-35" w.g. Venturi Scrubber	85-95%	50	15	5.1	0.6	"	"
"	Beloit	"	"	"	"	"	102	30	135.2	15.4	"	"
"	Howmet	"	"	"	"	"	102	30	135.2	15.4	"	"
"	Seamless Modena	"	"	"	"	"	74	22	24.0	2.7	"	"
"	King Foundaries	"	"	"	"	"	56	17	19.1	2.2	"	"
"	Link-Belt	"	"	"	"	"	0	0	15.4	15.4	"	"

See Page 1 of 5 for footnotes (1) and (2)

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: PRIMARY NONFERROUS METALS

INDUSTRY CODE: 08

PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (TON/YR.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING	REQUIRED	EXISTING	REQUIRED
St. Louis	Lewis Mathes Co.	Copper	42,500	1	(1)	--	--	--	38	38	Neg.	Neg.
"	St. Joseph Lead	Lead	200,000	1	"	--	--	--	1,140	1.140	4,500	4,500
"	Am. Zinc of Ill.	Zinc	69,000	1	"	--	--	--	166	166	1,450	1,450

(1) Current controls for copper, lead and zinc smelters indicated assumed 95% efficient for particulate and 49.9 efficient for sulfur dioxides, thus, no additional controls required.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: SULFURIC ACID INDUSTRY CODE: 09 PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST (1)		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Day)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL (2) ($1000/YR.)	EXISTING (4)	REQUIRED	EXISTING (4)	REQUIRED
Cinti.	American Cyanamide	Contact	90	1	Secondary Absorption Tower and Demister	(3)	501	109	174	106	1,780	249
"	E. I. Dupont	"	175	4	"	"	765	168	338	207	3,461	484
"	International Min. & Chem.	"	45	"	"	"	329	71	87	53	890	124
"	Mobile Chem.	"	25	"	"	"	229	49	48	29	494	69
St.Louis	Charles Pfizer	"	5	"	"	"	58	14	10	6	99	14
"	American Zinc	"	146	"	"	"	675	148	282	172	2,088	404
"	National Lead	"	500	"	"	"	1,469	343	967	591	9,890	1,384
Phila.	Atlantic-Richfield	"	140	"	"	"	656	144	271	165	2,769	387
"	E. I. Dupont	"	70	"	"	"	435	95	135	82	1,384	193
"	Rohm & Haas	"	88	"	"	"	495	108	170	104	1,740	243

(1) Control cost and emission estimates based on known capacity of plants.
(2) Annual cost does not include credit for additional sulfuric acid recovered.
(3) Required sulfur dioxide control of 86%; particulate control range from 43% to 93% according to plant size.
(4) Assumed average existing collection efficiency of: 46% for particulates; no control for sulfur dioxide.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: PHOSPHATE FERTILIZER

INDUSTRY CODE: 10

PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (1000 Ton/Yr)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING	REQUIRED	EXISTING	REQUIRED
Cinti.	Inter.Minerals & Chemicals	N.S.(2)	35e (2)	1.	(3)	(3)	(3)	(3)	3,150	3,150	Neg.	Neg.
"	Mobil Chem.Co.	N.S.	35e	1	"	"	"	"	3,150	3,150	"	"
"	Tennessee Corp	N.S.	100	1	"	"	"	"	9,000	9,000	"	"
" St.Louis	FS Services,Inc	N.S.	60	1	"	"	"	"	5,400	5,400	"	"
"	National Stockyard	N.S.	35e	1	"	"	"	"	3,150	3,150	"	"
Phila.	Kerr-McGee Chemical	N.S.	35e	1	"	"	"	"	3,150	3,150	"	"

(1) Normal superphosphate = N.S.

(2) "e" indicates plant capacity not known, thus, model plant of 35,000 Ton/Yr. was assumed for emission and control cost estimates; otherwise, estimates based on known plant capacity.

(3) Assumed fabric filters now used to control plants, thus, no additional controls required.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: PETROLEUM REFINING

INDUSTRY CODE: 11

PAGE 1 OF 2

		PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST (4)		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
AQCR	COMPANY	TYPE	CAPACITY (b/cd)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (5)	REQUIRED	EXISTING (5)	REQUIRED
Cinti.	Chevron Asphalt	Refinery	11,000	1	S.R.P.(2)	50	--	--	Neg.	Neg.	1,800	1,800
"	Gulf Oil Corp	Refinery	40,700	1	S.R.P.(3)	50	130	--	Neg.	Neg.	6,000	3,000
"	"	Cat Cracking	27,000(1)	1	H.E.E.P.(3)	82	130	25	30	6	Neg.	Neg.
St.Louis	Amer.Oil Co.	Refinery	86,500	1	S.R.P.	50	260	--	Neg.	Neg.	14,400	7,200
"	"	Cat Cracking	65,000(1)	1	H.E.E.P.	82	240	44	70	12	Neg.	Neg.
"	Clark Oil & Ref	Refinery	35,000	1	S.R.P.		120	--	Neg.	Neg.	6,000	3,000
"	"	Cat Cracking	14,000(1)	1	H.E.E.P.	82	100	20	14	2	Neg.	Neg.
"	Mobile Oil Co.	Refinery	47,000	1	S.R.P.	50	190	--	Neg.	Neg.	10,000	5,000
"	"	Cat Cracking	31,000(1)	1	H.E.E.P.	82	--		3	Neg.	Neg.	Neg.
"	Shell Oil Co.	Refinery	194,000	1	S.R.P.	50	450	--	Neg.	Neg.	32,000	16,000

(1) Capacity reported in b/sd (barrels per stream day).
(2) = Sulfur recovery plant for control of sulfur dioxide emissions.
(3) = High efficiency electrostatic precipitator for control of particulate emissions.
(4) Control cost and emission estimates based on known process size.
(5) Assumed average control of particulates from catalyst regenerator of 67%; refining existing controls of 67% particulate emission and 37% of sulfur dioxide emissions.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: PETROLEUM REFINING

INDUSTRY CODE: 11

PAGE 2 OF 2

		PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
AQCR	COMPANY	TYPE	CAPACITY (b/cd)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING	REQUIRED	EXISTING	REQUIRED
Phila.	Atlantic Richfield	Refinery	155,000	1	(6)	--	--	--	Neg.	Neg.	13,000	13,000
"	"	Cat Cracking	40,000(1)	1	H.E.E.P.(3)	82	180	36	44	8	Neg.	Neg.
"	Sun Oil Co.	Refinery	158,300	1	(6)	--	--	--	Neg.	Neg.	14,000	14,000
"	"	Cat Cracking	78,500 (1)	1	H.E.E.P.	82	260	56	86	14	Neg.	Neg.
"	Sinclair Ref.	Refinery	104,000	1	(6)	--	--	--	Neg.	Neg.	8,600	8,600
"	"	Cat Cracking	44,000 (1)	1	H.E.E.P.	82	200	40	56	10	Neg.	Neg.
"	Sun Oil Co.	Refinery	158,000	1	(6)	--	--	--	Neg.	Neg.	13,200	13,200
"	"	Cat Cracking	90,000 (1)	1	N.E.E.P.	82	160	32	38	7	Neg.	Neg.

See Page 1 of 2 for footnotes (1), (2), (3), (4) and (5).

(6) Sulfur recovery plant now in operation.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: ASPHALT BATCHING

INDUSTRY CODE: 12

PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST (3)		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Yr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING (2)	REQUIRED
	Model Plant	Asphaltic Concrete	510,000	1	10" w.g. (2) Venturi Scrubber	98.2	14.0	11.3	870	57	Neg.	Neg.
Cinti	(1)	"	10,200,000	20	"	"	280	226	17,400	1,140	Neg.	Neg.
Wash.	"	"	7,650,000	15	"	"	210	170	13,050	855	"	"
St.Louis	"	"	3,060,000	6	"	"	84	68	5,220	342	"	"
Phila.	"	"	15,810,000	31	"	"	434	350	26,970	1,767	"	"

(1) A list of the asphalt batching plants which operated in the selected AQCR's in 1967 may be found on the following page.

(2) All asphaltic concreteplants were assumed to have process cyclones, reducing particulate emissions by 80%

(3) Control cost and emission estimates based on model plant indicated.

ASPHALT BATCHING

AQCR	PLANT NAME
Phila.	Union Paving Co.
	Eastern Asphalt Co. (2 plants)
	Flintkote Co.
	Philgite Co., Inc.
	Warner Co.
	Dover Equipment and Machine
	Asphalt Industries, Inc.
	Miller Quarries, Inc. (2 plants)
	Interstate Amiesite Corp.
	Ackworth Materials Corp.
	Ackworth Materials Corp.
	Asphalt Paving and Supply Co.
	Newport Paving Supply Co.
	JDM Materials Co., Inc.
	Highway Materials, Inc.
	Newport Paving Supply Co.
	Bucks Co. Asphalt Co.
	Bucks Co. Asphalt Co.
	Highway Materials Co.
	Highway Materials Co.
	Union Paving Co.
	M & M Stone Co., Inc.
	Eureka Stone Quarry, Inc.
	Union Paving Co.
	Barrett Paving Mixtures
	Dover Equipment and Machine Co.
	Saienni Bros.
	Warren Brow. Co., Inc.
	Petrillo Bros., Inc.
D. C.	Fairfax Asphalt Co., Inc.
	Kensington Bituminous Corp.
	F. O. Day Bituminous Co.
	Arlington Asphalt Co.
	Arlington Asphalt Co.
	Prince Georges Bituminous Co.

ASPHALT BATCHING (CONTINUED)

AQCR	PLANT NAME
(D. C.)	Prince Georges Bituminous Co.
	Washington Contractors, Inc.
	National Asphalt Paving Corp.
	National Asphalt Paving Corp.
	Arlington Asphalt Co., Inc.
	Newton Asphalt Co., Inc.
	Troxler Asphalt Co., Inc.
	Bituminous Construction Co.
	Plasma Chem. Systems, Inc.
Cincinnati	Northern Ky. Asphalt Co.
	Armrel Construction Co., Inc.
	Eaton Asphalt Paving Co., Inc
	Byrnes-Conway Co. (2 plants)
	Eaton Asphalt Paving Co., Inc.
	Paz-O-Products, Inc.
	Chevron Asphalt Co.
	Brewer Co.
	Brewer Co.
	Brewer Co.
	Brewer Co.
	Bitucote Products Co.
	Northern Ky. Asphalt Co.
	Valley Asphalt Corp.
	Allied Chemical Corp. (2 plants)
	Triasco Paving Corp.
	Hotmix, Inc.
	Great Lakes Asphalt, Inc.
	Barrett
St. Louis.	Bitucote Products Co.
	Asphalt Material Co., Inc.
	Trumbell Asphalt Co. of Delaware
	Asphaltic Concrete Corp.
	Asphaltic Concrete Corp.
	Ken-Mar Venetian Blind Co.
	Bitumix, Inc.

Source: Dun & Bradstreet Computer Printout.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: CEMENT

INDUSTRY CODE: 13

PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST (2)		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (10^6bbl/yr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (3)	REQUIRED	EXISTING	REQUIRED
St.Louis	River Cement Co.	Dry	3.0	1	Fabric Filter	>99	665	189	2,256	451	Neg.	Neg.
"	Alpha Portlant	Wet	2.6	1	E.S.P. (1)	>99	839	186	1,683	112	"	"
"	Missouri Portland	Wet	5.0	1	E.S.P.	>99	1,395	312	3,238	32	"	"

(1) E.S.P. = electrostatic precipitators.
(2) Control cost and emission estimates based on known plant size.
(3) Assumed all plants currently control to 95%.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: LIME

INDUSTRY CODE: 14

PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Day)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
Phila.	G & W. H. Carson	(1)	(1)	1	Venturi Scrubber	97	50	69	1,209	97	Neg.	Neg.
"	Amos K. Stoltzfus	(1)	(1)	1	"	"	50	69	1,209	97	"	"
"	Everett V. Moser	(1)	(1)	1	"	"	50	69	1,209	97	"	"

(1) Control cost and emission estimates based on a model plant of 500 ton/day - 80% of capacity in a single rotary kiln, the remainder in a vertical kiln.

(2) Assumed vertical kilns are currently uncontrolled and vertical kilns generally controlled to 80%.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: COAL CLEANING

INDUSTRY CODE: 15

PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (1000 Ton/Yr)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
St.Louis "	Belle-Valley Coal	(1)	120	1	(1)	(1)	57	10	23.8	9.0	Neg.	Neg.
"	Peabody Coal	"	3,304	1	"	"	1,582	271	129.5	64.9	"	"
"	Peabody Coal	"	869	1	"	"	416	71	58.5	23.5	"	"

(1) Control costs and emission estimates based on known capacity and model plant (which identifies the process elements in model plant). Model plant is comprised of the following unit processes and percent of total plant capacity: pneumatic cleaners (7.1%); fluidized-bed driers (8.4%); and flash driers (56.5%)- percentage of production not indicated is assumed air dried with negligible emissions. Wet scrubbers were required control.

(2) Current control on 87% flash and fluidized driers is 80%; 16% of pneumatic cleaners now controlled at 80%.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GRAIN MILLING

INDUSTRY CODE: 16

PAGE 1 OF 1

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Yr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
	Model Plant	Animal Feed Mill	200,000 T/Yr.	1	Fabric Filter	99	20	7	350	54	Neg.	Neg.
Cinti.	(1)	"	1,400,000	7	"	"	140	49	2,450	378	Neg.	Neg.
Wash.	"	"	600,000	3	"	"	60	21	1,050	162	"	"
St.Louis	"	"	3,600,000	18	"	"	360	126	6,300	972	"	"
Phila.	"	"	2,800,000	14	"	"	280	98	4,900	756	"	"

(1) Control cost and emission estimates based on model plant indicated. A list of animal feed mills which operated in the selected AQCR's in 1967 may be found on the following page.

(2) Assumed 50% of all plants were controlled with mechanical collectors to an efficiency of 70%.

GRAIN MILLING

AQCR	PLANT NAME
D. C.	Bowman Bros. Inc.
	Chesapeake Feed Co.
	Binger Bros. Ind.
Phila.	Atlas Canine Products, Inc.
	Pet Foods, Inc.
	Bausman Pet Supplies
	Seaboard Supply Co.
	Thrivo Co., Inc.
	Crisfield Dehydrating Co., Inc.
	Rosenberg Ben, Inc.
	Amburgo Manufacturing Co., Inc.
	R. F. French Co.
	Deer Run Packing Co., Inc.
	Greater Valley Feed Co., Inc.
	Wilson Phrm. and Chemical
	Wafer Mills Co., Inc.
	American Pet Food Corp.
St. Louis	Ralston Purina Co.
	Textron Inc. Del.
	Cardinal Food Products, Inc.
	Campbell and Co., Inc.
	Ultra-Life Laboratories, Inc.
	Dixie Mills Co.
	Consumers Products Co., Inc.
	Allied Mills, Inc.
	Joggerst Milling Co.
	Chesterfield Elev. & Sup. Co.
	Agway, Inc.
	Gordon Foods Div.
	Van Camp Div.
	International Multifoods Corp.
	Nutreana Mills Div.
	Professional Feeds
	Agway, Inc.
	Fenton Feed Mill & Welding Co.

GRAIN MILLING (CONTINUED)

AQCR	PLANT NAME
Cincinnati	Cooperative Mills, Inc. Kentucky Chemicals Industry Dearborn Mills Co. Clark Selma Mis. J.E. Midwest Feeds Co., Inc. Ralston Purina Co. Thorobred Co., Inc.

Source: Dun & Bradstreet Computer Printout.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GRAIN HANDLING INDUSTRY CODE: 17 PAGE 1 OF 2

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (1000 Bushels)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (3)	REQUIRED	EXISTING	REQUIRED
	Model Plants	Country	0-25 (1)	1	Fabric Filters	99	2.7	1.0	1.6	Neg.	Neg.	Neg.
	"	"	25-75	1	"	"	5.4	1.9	6.3	0.1	"	"
	"	"	75-150	1	"	"	12.4	4.4	14.1	0.1	"	"
	"	"	150-250	1	"	"	22.5	7.9	25.0	0.3	"	"
	"	"	250-500	1	"	"	52.0	18.2	46.8	0.5	"	"
	"	Terminal	500-1000	1	"	"	84.0	29.4	390.0	6.0	"	"
	"	"	1000-2500	1	"	"	195.0	68.2	910.0	14.0	"	"
	"	"	2500-5000	1	"	"	420.0	147.0	1,950.0	30.0	"	"
	"	"	5000-10,000	1	"	"	840.0	294.0	3,900.0	60.0	"	"
	"	"	10,000 +	1	"	"	1,110.0	388.0	7,800.0	120.0	"	"
Cinti	(2)	Country	25-75	1	"	"	5.4	1.9	6.3	0.1	"	"
"	"	"	150-250	3	"	"	67.5	23.7	75.0	0.9	"	"
"	"	"	250-500	4	"	"	208.0	72.8	187.2	2.0		
"	"	Terminal	500-1000	6	"	"	504.0	176.4	2,340.0	36.0	"	"
"	"	"	1000-2500	4	"	"	780.0	272.8	3,640.0	56.0	"	"
"	"	"	2500-5000	3	"	"	1,260.0	441.0	5,850.0	90.0	"	"

(1) Range of processes sizes.
(2) Control cost and emission estimates based on model plants indicated. No grain handling plants were identified by name.
(3) None of the country-type elevators were assumed controlled - one-half of the larger terminal elevators were controlled to 70%.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: GRAIN HANDLING

INDUSTRY CODE: 17

PAGE 2 OF 2

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (1000 Bushels)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (3)	REQUIRED	EXISTING	REQUIRED
St.Louis	(2)	Country	0-25	1	Fabric Filters	>99	2.7	1.0	1.6	Neg.	Neg.	Neg.
"	"	"	25-75	3	"	"	16.2	5.7	18.9	0.3	"	"
"	"	"	75-150	7	"	"	86.8	30.8	98.7	0.7	"	"
"	"	"	150-250	3	"	"	67.5	23.7	75.0	0.9	"	"
"	"	"	250-500	7	"	"	364.0	127.4	327.6	3.5	"	"
"	"	Terminal	500-1000	6	"	"	504.0	176.4	2,340.0	36.0	"	"
"	"	"	1000-2500	5	"	"	975.0	341.0	4,550.0	70.0	"	"
"	"	"	2500-5000	8	"	"	3,360.0	1,176.0	15,600.0	240.0	"	"
"	"	"	5000-10,000	2	"	"	1,680.0	588.0	7,800.0	120.0	"	"
Phila.	"	Terminal	500-1000	1	"	"	84.0	29.4	390.0	6.0	"	"
"	"	"	100-2500	1	"	"	195.0	68.2	910.0	14.0	"	"

See Page 1 of 1 for footnotes (1), (2) and (3).

SECONDARY NONFERROUS METALLURGICAL

AQCR	PLANT NAME	METAL TYPE
D. C.	Bladensburg Metals	Secondary Lead, Tin, Babbitt, Solder, Aluminum, Lead, Brass, Copper, Sec. Lead
	Hyman Viener & Sons	Lead, Tin, Babbitt, Solder, Zinc.
Phila.	Atlantic Metals Corporation	Aluminum
	General Smelting Company	Aluminum, Zinc.
	Metallurgical Products Company	Aluminum, Brass, Copper
	George Sall Metals Company	Aluminum, Lead, Brass, Copper, Zinc.
	North American Smelting Company	Aluminum, Brass, Copper, Sec. Lead, Tin, Babbitt, Solder
	Joseph Rosenthal's Sons, Inc.	Lead
	Bers & Company, Inc.	Lead
	Electric Storage Battery Company	Lead
	Franklin Smelting & Refining Company	Lead, Brass, Copper, Zinc
	Thomas F. Lukens	Lead, Sec. Lead, Tin, Babbitt, Solder
	National Lead Company	Lead
	Joseph Rosenthal's Sons, Inc.	Lead, Brass, Copper
	U. S. Smelting Works	Lead, Sec. Lead, Tin, Babbitt, Solder
	Ajax Metal, Division of H. Kramer	Brass, Copper
	L. Goldstein's Sons, Inc.	Brass, Copper
	Metal Bank of America	Brass, Copper
	Thermal Reduction Corporation	Brass, Copper
	Acme Alloys, Inc.	Lead, Tin, Babbitt, Solder
	Bers & Company, Inc.]	Lead, Tin, Babbitt, Solder
	Halpern Metals Company	Lead, Tin, Babbitt, Solder
	National Lead Company	Lead, Tin, Babbitt, Solder

SECONDARY NONFERROUS METALLURGICAL (CONTINUED)

AQCR	PLANT NAME	METAL TYPE
St. Louis	A. Perez & Son, Div. of Abrams Metal Co.	Lead, Tin, Babbitt, Solder
	Besco Metals Corporation	Zinc
	Superior Zinc Corporation	Zinc
	Superior Zinc	Zinc
	Deleware Valley Smelting Corp.	Zinc
	Lefton Iron & Metal Company	Aluminum
	Aluminum Service Corp.	Aluminum
	Grossman Smelting Company	Aluminum, Brass, Copper, Zinc
	M. Holtzman Metal Company	Aluminum, Brass, Copper, Lead, Tin, Babbitt, Solder, Zinc
	Lewin Mathes Co., Div. of Cerro de Pasco Corporation	Aluminum, Lead, Brass, Copper, Secondary Lead, Babbitt, Solder, Zinc
	Lewin Mathes Metals Div., Cerro de Pasco Corporation	Lead, Brass, Copper, Zinc
	American Zinc, Lead, & Smelting Co.	Lead, Tin, Babbitt, Solder, Zinc
	Federated Div. of Amer. Smelting and Refining Company	Aluminum
	National Lead Company	Lead
	American Zinc, Lead & Smelting Co.	Lead
	Theo. Hiertz Metal Company	Lead, Tin, Babbitt, Solder
	National Lead Company	Lead, Tin, Babbitt, Solder
	Shanfield Brothers Metal Company	Lead, Tin, Babbitt, Solder, Zinc
	American Zinc Co. of Ill.	Zinc.
	American Zinc, Lead and Smelting Co.	Lead, Tin, Babbitt, Solder, Zinc.
	Monsanto Chemical Company	Zinc.

SECONDARY NONFERROUS METALLURGICAL (CONTINUED)

AQCR	PLANT NAME	METAL TYPE
Cincinnati	American Compressed Steel Corp.	Aluminum, Lead, Secondary Lead, Tin, Babbitt, Solder, Zinc
	G. A. Avril Company	Aluminum, Lead, Secondary, Lead, Tin, Babbitt, Solder, Zinc
	Certified Metals Mfg. Company	Aluminum, Lead, Secondary Lead, Tin, Babbitt, Solder, Zinc.
	Eagle-Picher Company	Lead, Secondary Lead, Tin, Babbitt, Solder
	National Lead Company	Lead, Tin, Babbitt, Solder
	Moskowitz Brothers	Lead, Tin, Babbitt, Solder
	National Lead Company	Lead, Secondary Lead, Tin, Babbitt, Solder

Source: The Waste Trade Directory 1967 (1966-67 ec.). New York: Atlas Publishing Co., 1967.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: SECONDARY NON-FERROUS METALS

INDUSTRY CODE: 18

PAGE 1 OF 2

		PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
AQCR	COMPANY	TYPE	CAPACITY (Ton/Yr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
	Model Plant	Alum.	4,300	4	Wet Scrubber	95	82	26	8.7	1.0	Neg.	Neg.
	"	Copper, Brass, & Bronze	5,500	6	Fabric Filter	95	140	54	65.0	6.5	"	"
	"	Lead	1,200	1	Fabric Filter	95	15	5	34.0	3.4	"	"
	"	Zinc	240		Fabric Filter	95	5	1	1.6	0.2	"	"
Cinti.	(1)	Alum.	12,900	3	Wet Scrubber	95	246	78	26.1	3.0	"	"
"	"	Lead	8,400	7	Fab. Filter	"	105	35	238.0	23.8	"	"
"	"	Zinc	720	3	"	"	15	3	4.8	0.6	"	"
Wash.	"	Alum.	4,300	1	Wet Scrubber	"	82	26	8.7	1.0	"	"
"	"	Copper	6,500	1	Fab. Filter	"	140	54	65.0	6.5	"	"
"	"	Lead	480	2	"	"	30	10	68.0	6.8	"	"
"	"	Zinc	240	1	"	"	5	1	1.6	0.2	"	"
St.Louis	"	Alum.	25,800	6	Wet Scrubber	"	492	156	52.2	6.0	"	"
"	"	Copper	26,000	4	Fab. Filter	"	560	216	260.0	26.0	"	"

(1) Control costs and emission estimates based on model plants indicated. A list of plant names are included on the following page.
(2) Assumed 50% of plants currently control with efficiency of 95%.

Table 5-5. INDUSTRIAL PROCESSES

INDUSTRY: SECONDARY NON-FERROUS METALS INDUSTRY CODE: 18 PAGE 2 OF 2

AQCR	COMPANY	PROCESS			ADDITIONAL CONTROLS REQUIRED		FULL ADDITIONAL CONTROL COST		EMISSION DATA (TON/YEAR)			
									PARTICULATES		SULFUR DIOXIDE	
		TYPE	CAPACITY (Ton/Yr.)	NUMBER	TYPE	EFFICIENCY (%)	INVESTMENT ($1000)	ANNUAL ($1000/YR.)	EXISTING (2)	REQUIRED	EXISTING	REQUIRED
St.Louis (Con't.)	(1)	Lead	12,000	10	Fab. Filter	95	150	50	340.0	34.0	Neg.	Neg.
"	"	Zinc	2,160	9	"	"	45	9	14.4	1.8	"	"
Phila.	"	Alum.	17,200	4	Wet Scrubber	"	328	104	34.8	4.0	"	"
"	"	Copper	58,500	9	Fab. Filter	"	1,260	486	585.0	58.5	"	"
"	"	Lead	18,000	15	"	"	225	75	510.0	51.0	"	"
"	"	Zinc	1,680	7	"	"	35	7	11.2	1.4	"	"

See Page 1 of 2 for footnotes (1) and (2).

emissions as well as in determining the adequacy of the existing control system to meet emissions standards. Finally, the "year built" (as found with municipal incinerators) is identified since the control-cost-estimating procedure is dependent upon the age of the facility.

The data observed in Tables 5-2 through 5-5 have been presented to facilitate comparisons between the data used in the 305(a) Approach and the data and results obtained through the Extrapolation and Aggregation Approaches. To further simplify the comparisons, summaries of regional emission estimates and control costs are presented in Tables 5-6 and 5-7.

The efforts involved in Step #1 of the 305(a) Approach are nearly all data handling tasks, that is, accounting efforts. The data bank supporting the ECA Report is partially computerized, and part of the data is stored in files and in other locations. The Step #1 task was one of obtaining and organizing the data.

There was some engineering analysis required in Step #1. Control efficiencies for specific processes were necessary on a process-by-process basis and were easily determined (along with the quantity of controlled and uncontrolled emissions). Also, thermal balance calculations were required to determine the quantities of low-sulfur oil and natural gas. Such calculations were required because the analysis presented here is conducted on a regional level while the ECA Report procedures are designed for calculating national control cost estimates.

5.2.5 305(a) Approach - Step #2

Step #2 requires that the data organized in Step #1 be presented in a form most useful to the decision-maker. In this report, the data has been aggregated for each AQCR investigated. If the relevant data was available for the entire nation, such demand estimates could be presented for entire states, multi-state regions and/or the nation.

The demand estimates are presented in Table 5-8 through 5-11 for the four AQCRs. In addition to the basic data developed in Step #1, data on "typical gas volumes" has been included to present rough indication of the size control systems that are required for each process type. The data on gas volumes was obtained from various sources in the literature.

Table 5-6. REGIONAL EMISSION SUMMARY BY SOURCE CATEGORY

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AIR QUALITY CONTROL REGION: CINCINNATI

SOURCE CATEGORY	1967 EMISSION BY SOURCE CATEGORY (Ton/Yr.)			
	PARTICULATES		SULFUR DIOXIDE	
	Uncontrolled	Controlled	Uncontrolled	Controlled
Solid waste	16,695	2,814		
Steam-electric Power	34,780	2,126	183,952	18,394
Industrial Boilers	37,100	1,600	33,600	12,200
Commercial and Instit. Heat.	854	264	3,100	2,280
Residential Heating	2,936	420	8,600	3,000
Iron and Steel	8,163	1,107	-	-
Gray Iron Foundry	1,762	240	-	-
Primary Nonferrous Metals	-	-	-	-
Sulfuric Acid	647	395	6,625	926
Phosphate Fertilizers	15,300	15,300	-	-
Petroleum Refining	30	6	7,800	4,800
Asphalt	17,400	1,140	-	-
Cement	-	-	-	-
Lime	-	-	-	-
Coal Cleaning	-	-	-	-
Grain Milling	2,450	378	-	-
Grain Handling	12,099	185	-	-
Secondary Nonferrous Metals	269	27		
Regional Total	150,485	26,002	243,677	41,600

Table 5-6. REGIONAL EMISSION SUMMARY BY SOURCE CATEGORY (Con't.)

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AIR QUALITY CONTROL REGION: WASHINGTON, D.C.

SOURCE CATEGORY	1967 EMISSION BY SOURCE CATEGORY (Ton/Yr.)			
	PARTICULATES		SULFUR DIOXIDE	
	Uncontrolled	Controlled	Uncontrolled	Controlled
Solid Waste	33,311	4,482	-	-
Steam-electric Power	21,831	1,557	70,925	9,768
Industrial Boilers	-	-	-	
Commercial and Instit. Heating	1,975	1,309	13,030	11,090
Residential Heating	5,410	910	12,600	9,000
Iron and Steel	-	-	-	-
Gray Iron Foundry	-	-	-	-
Primary Nonferrous Metals	-	-	-	-
Sulfuric Acid	-	-	-	-
Phosphate Fertilizers	-	-	-	-
Petroleum Refining	-	-	-	-
Asphalt	13,050	855	-	-
Cement	-	-	-	-
Lime	-	-	-	-
Coal Cleaning	-	-	-	-
Grain Milling	1,050	162	-	-
Grain Handling	-	-	-	-
Secondary Nonferrous Metals	143	15		
Regional Total	76,760	9,290	96,555	29,858

Table 5-6. REGIONAL EMISSION SUMMARY BY SOURCE CATEGORY (Con't.)

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AIR QUALITY CONTROL REGION: ST. LOUIS

SOURCE CATEGORY	1967 EMISSION BY SOURCE CATEGORY (Ton/Yr.)			
	PARTICULATES		SULFUR DIOXIDE	
	Uncontrolled	Controlled	Uncontrolled	Controlled
Solid Waste	22,978	2,223	-	-
Steam-electric Power	43,798	4,313	234,679	25,041
Industrial Boilers	87,600	9,800	145,000	40,000
Commercial and INstit. Heating	334	334	2,820	2,820
Residential Heating	6,990	665	18,800	5,050
Iron and Steel	20,394	767	-	-
Gray Iron Foundry	749	135	-	-
Primary Nonferrous Metals	1,344	1,344	-	-
Sulfuric Acid	1,259	769	12,077	1,802
Phosphate Fertilizers	8,550	8,550	-	-
Petroleum Refining	187	32	62,400	31,200
Asphalt	5,220	342	-	-
Cement	7,177	189	-	-
Lime	-	-	-	-
Coal Cleaning	212	97	-	-
Grain Milling	6,300	972	-	-
Grain Handling	30,812	471	-	-
Secondary Nonferrous Metals	667	68	-	-
Regional Total	244,571	31,071	475,776	105,913

Table 5-6. REGIONAL EMISSION SUMMARY BY SOURCE CATEGORY (Con't.)

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AIR QUALITY CONTROL REGION: PHILADELPHIA

SOURCE CATEGORY	1967 EMISSION BY SOURCE CATEGORY (Ton/Yr.)			
	PARTICULATES		SULFUR DIOXIDE	
	Uncontrolled	Controlled	Uncontrolled	Controlled
Solid Waste	58,293	7,954		
Steam-electric Power	67,462	6,882	309,404	34,198
Industrial Boilers	174,000	15,800	300,000	122,000
Commercial and Instit. Heating	3,540	2,350	23,930	20,200
Residential Heating	8,710	4,400	35,050	31,000
Iron and Steel	58,428	3,771	-	-
Gray Iron Foundry	1,363	168	-	-
Primary Nonferrous Metals	-	-	-	-
Sulfuric Acid	576	351	5,893	823
Phosphate Fertilizers	3,150	3,150	-	-
Petroleum Refining	224	39	48,800	48,800
Asphalt	26,970	1,767	-	-
Cement	-	-	-	-
Lime	3,627	291	-	-
Coal Cleaning	-	-	-	-
Grain Milling	4,900	756	-	-
Grain Handling	1,200	20	-	-
Secondary Nonferrous Metals	1,141	115	-	-
Regional Total	413,584	47,814	723,077	257,021

Table 5-7. PARTICULATE & SULFUR DIOXIDE CONTROL COST SUMMARY FOR SELECT AIR QUALITY CONTROL REGIONS

SOURCE CATEGORY	REGIONAL CONTROL COST PER SOURCE CATEGORY ($1000) FOR 1967							
	CINCINNATI		WASHINGTON		ST. LOUIS		PHILADELPHIA	
	INV.	ANNUAL	INV.	ANNUAL	INV.	ANNUAL	INV.	ANNUAL
Solid Waste	2,671	1,637	5,560	3,120	2,239	1,454	11,046	5,646
Steam-electric Power	27,137	8,415	35,270	6,080	23,804	7,488	53,126	17,195
Industrial Boilers	8,826	7,962	-	-	8,894	16,052	15,609	10,445
Comm.& Inst.Heating	726	410	671	1	-	-	1,426	38
Residential Heating	-	-	-	-	-	-	-	-
Iron and Steel	8,585	3,683	-	-	13,923	6,395	39,727	18,440
Gray Iron Foundry	1,525	456	-	-	698	211	1,348	435
Prim.Nonfer.Metals	-	-	-	-	-	-	-	-
Sulfuric Acid	1,824	397	-	-	2,202	505	1,586	347
Phosphate Fert.	-	-	-	-	-	-	-	-
Petroleum Refining	260	25	-	-	1,670	124	800	164
Asphalt	280	226	210	170	84	68	434	350
Cement	-	-	-	-	2,899	687	150	207
Lime	-	-	-	-	-	-	-	-
Coal Cleaning	-	-	-	-	2,055	352	-	-
Grain Milling	140	49	60	21	360	126	280	98
Grain Handling	2,825	999	-	-	7,056	2,470	279	98
Secondary Non.Met.	366	116	257	91	1,247	431	1,848	672
Regional Total	55,165	23,555	42,028	9,482	67,131	36,363	127,659	54,135

TABLE 5-8. CONTROL SYSTEM DEMAND FOR THE CINCINNATI AQCR

SOURCE CODE	SOURCE CATEGORY AND PROCESS	TYPICAL CONTROL SYSTEM TYPE	NUMBER OF SYSTEMS REQUIRED	SUBSTITUTE FUELS REQUIRED			TOTAL ADDITIONAL CONTROL INVESTMENT ($1000)	[illegible]		[illegible]
				OIL		NAT. GAS				
				QUANTITY (10^6 Gal)	SULFUR CONTENT (%)	QUANTITY (10^6 cf)		[illegible]	[illegible]	
01	SOLID WASTE DISPOSAL									
	• Municipal Incinerators (Existing)	• Wet Scrubber	16	---	---	---	1,129	[illegible]	[illegible]	[illegible]
	• Domestic and Commercial Incinerators	• Wet Scrubber	(4)	---	---	---	1,542	[illegible]	[illegible]	[illegible]
02	STEAM-ELECTRIC POWER GENERATION									
	• Boiler Flue Gas	• Wet Limestone Scrubbing	(5)	---	---	---	27,137	(2)	[illegible]	[illegible]
03	INDUSTRIAL BOILERS									
	• Boiler	• Switch to Oil with Sulfur Content less than 1.38%	N/A	138	---	0	8,826	(2)		[illegible]
04	COMMERCIAL-INSTITUTIONAL HEATING PLANTS									
	• Boilers	• Switch to low Sulfur Oil and Natural Gas	N/A	9	---	310	726	(2)	(3)	N/A
05	RESIDENTIAL HEATING PLANTS									
	• Home Heating Units	• Conversion to Distillate Oil and Natural Gas	N/A	9	---	4,980	(1)	(2)	(3)	N/A
06	IRON AND STEEL									
	• Open Hearth	• 40" w.g. Venturi Scrubber	19	---	---	---	8,385	N/A	89.5-97.5	10-650
	• Electric Furnace	• High Temperature Fabric Filter	4	---	---	---		N/A	84-95	30-400
	• Sintering	• 20" w.g. Wet Scrubber	0	---	---	---	---	N/A	95-98.8	10-400
07	GREY IRON FOUNDRY									
	• Cupola	• 16-35" w.g. Wet Scrubber	15	---	---	---	[illegible]	N/A	85-95	5-150
08	PRIMARY NON-FERROUS METALS									
	• Copper									
	• Smelter	• Acid Plant with Lime Scrubber	0	---	---	---	---	~94	~95	10-500
	• Lead									
	• Refinery	• Acid Plant	0	---	---	---	--	~96	~95	15-300
	• Zinc									
	• Smelter	• Acid Plant	0	---	---	---	---	~93	~95	10-500
09	SULFURIC ACID									
	• Contact Process	• Secondary Absorption Tower	4	---	---	---	1,824	~56	~67	6.5-90
10	PHOSPHATE FERTILIZER									
	• Normal Superphosphate	• Fabric Filter	0	---	---	---	---	N/A	0-80	20-80
11	PETROLEUM REFINING									
	• Refinery	• Sulfur Recovery Plants	2	---	---	---	130	~62	~90	100-1500
	• Catalyst Regenerators	• High Efficiency Electrostatic Precipitators	1	---	---	---	130	N/A	~90	20-300
12	ASPHALT BATCHING									
	• Asphalt Batching Process	• 10" w.g. Wet Scrubber	20	---	---	---	280	N/A	79-98.2	10-60
13	CEMENT									
	• Dry Kiln	• Fabric Filter	0	---	---	---	---	N/A	97.8-99.9	[illegible]-300
	• Wet Kiln	• Electrostatic Precipitator	0	---	---	---	---	N/A	97.6-99.6	60-650
14	LIME									
	• Vertical Kiln	• Cyclonic Scrubber	0	---	---	---	---	N/A	[illegible]-90	5-15
	• Rotary Kiln	• Venturi Scrubber	0	---	---	---	---	N/A	[illegible]-99.[illegible]	50-125
15	COAL CLEANING									
	• Fluidized-Bed Drier	• 15" w.g. Venturi Scrubber	0	---	---	---	---	N/A	~[illegible].8	10-150
	• Flash Drier	• 10" w.g. Venturi Scrubber	0	---	---	---	---	N/A	~[illegible].2	10-150
	• Pneumatic Cleaner	• 10" w.g. Venturi Scrubber	0	---	---	---	---	N/A	~94.5	
16	GRAIN MILLING									
	• Animal Feed Milling	• Fabric Filter	7	---	---	---	140	N/A	~99	30-130
17	GRAIN HANDLING									
	• Country Elevators	• Fabric Filter	8	---	---	---	281	N/A	~[illegible]	
	• Terminal Elevators	• Fabric Filter	13	---	---	---	2,544	N/A	~[illegible]	
18	SECONDARY NONFERROUS METALS									
	• Aluminum Melting									
	• Reverberatory Furnace	• Wet Scrubber	3	---	---	---	246	N/A	~[illegible]	10-50
	• Brass and Bronze Melting									
	• Reverberatory	• Fabric Filter	0	---	---	---	---	N/A	~[illegible]	9-50
	• Lead Refining									
	• Cupola	• Fabric Filter	7	---	---	---	105	N/A	~9[illegible]	10-50
	• Zinc Melting									
	• Galvanizing Kettles	• Fabric Filter	3	---	---	---	15	N/A	~[illegible]	10-50
	REGIONAL TOTAL	---	---	156	---	5,290	55,165	---	---	---

(1) Natural transition from coal to oil, gas and electric heating, thus no control costs.

(2) Allowable emission rate of 1.46 pounds of sulfur dioxide per million BTU input (control efficiency dependent on sulfur content of existing fuel).

(3) Allowable emission rate determined by combustion regulation of State of Maryland (see Figure E-2 in Appendix E).

(4) Number of control systems for domestic and commercial incinerators and new municipal incinerators not identified.

(5) Number of power plants is indicated (not the number of boilers).

TABLE 5-9. CONTROL SYSTEM DEMAND FOR THE WASHINGTON, D.C. AQCR

SOURCE CODE	SOURCE CATEGORY AND PROCESS	TYPICAL CONTROL SYSTEM TYPE	NUMBER OF SYSTEMS REQUIRED	SUBSTITUTE FUELS REQUIRED			TOTAL ADDITIONAL CONTROL INVESTMENT ($1000)	[illegible]		[illegible]
				OIL		NAT. GAS				
				QUANTITY (10^6 Gal)	SULFUR CONTENT (%)	QUANTITY (10^6 ft)		SULFUR DIOXIDE	PARTICULATES	[illegible]
01	SOLID WASTE DISPOSAL									
	• Municipal Incinerators (Existing)	• Wet Scrubber	8	---	---	---	1,521		[illegible]	[illegible]
	• Domestic and Commercial Incinerators	• Wet Scrubber	(4)	---	---	---	4,039	[illegible]	85-95	[illegible]
02	STEAM-ELECTRIC POWER GENERATION									
	• Boiler Flue Gas	• Wet Limestone Scrubbing	$6^{(5)}$	---	---	---	35,270	(2)	[illegible]	[illegible]
03	INDUSTRIAL BOILERS									
	• Boiler	• Switch to Oil with Sulfur Content less than 1.38%	N/A	0	---	0	0	[illegible]		[illegible]
04	COMMERCIAL-INSTITUTIONAL HEATING PLANTS									
	• Boilers	• Switch to low Sulfur Oil and Natural Gas	N/A	5	---	580	621	(2)	[illegible]	N/A
05	RESIDENTIAL HEATING PLANTS									
	• Home Heating Units	• Conversion to Distillate Oil and Natural Gas	N/A	29	---	4,620	(1)	(2)	(1)	N/A
06	IRON AND STEEL									
	• Open Hearth	• 40" w.g. Venturi Scrubber	---	---	---	---	---	N/A	89.5-97.5	10-650
	• Electric Furnace	• High Temperature Fabric Filter	---	---	---	---	---	N/A	84-95	30-400
	• Sintering	• 20" w.g. Wet Scrubber	---	---	---	---	---	N/A	95-98.8	[illegible]
07	GREY IRON FOUNDRY									
	• Cupola	• 16-35" w.g. Wet Scrubber	---	---	---	---	---	N/A	85-95	5-150
08	PRIMARY NON-FERROUS METALS									
	• Copper									
	• Smelter	• Acid Plant with Lime Scrubber	---	---	---	---	---	~94	~95	10-500
	• Lead									
	• Refinery	• Acid Plant	---	---	---	---	---	~96	~95	15-300
	• Zinc									
	• Smelter	• Acid Plant	---	---	---	---	---	~93	~95	10-500
09	SULFURIC ACID									
	• Contact Process	• Secondary Absorption Tower	---	---	---	---	---	~86	~67	6.5-90
10	PHOSPHATE FERTILIZER									
	• Normal Superphosphate	• Fabric Filter	---	---	---	---	---	N/A	0-80	20-80
11	PETROLEUM REFINING									
	• Refinery	• Sulfur Recovery Plants	---	---	---	---	---	~62	~90	100-1500
	• Catalyst Regenerators	• High Efficiency Electrostatic Precipitators	---	---	---	---	---	N/A	~90	20-300
12	ASPHALT BATCHING									
	• Asphalt Batching Process	• 10" w.g. Wet Scrubber	15	---	---	---	210	N/A	79-98.2	10-60
13	CEMENT									
	• Dry Kiln	• Fabric Filter	---	---	---	---	---	N/A	97.8-99.9	40-300
	• Wet Kiln	• Electrostatic Precipitator	---	---	---	---	---	N/A	97.6-99.6	60-650
14	LIME									
	• Vertical Kiln	• Cyclonic Scrubber	---	---	---	---	---	N/A	50-90	5-15
	• Rotary Kiln	• Venturi Scrubber	---	---	---	---	---	N/A	97.8-99.[illegible]	50-125
15	COAL CLEANING									
	• Fluidized-Bed Drier	• 15" w.g. Venturi Scrubber	---	---	---	---	---	N/A	~97.8	10-150
	• Flash Drier	• 10" w.g. Venturi Scrubber	---	---	---	---	---	N/A	~93.2	10-150
	• Pneumatic Cleaner	• 10" w.g. Venturi Scrubber	---	---	---	---	---	N/A	~94.5	
16	GRAIN MILLING									
	• Animal Feed Milling	• Fabric Filter	3	---	---	---	60	N/A	~99	30-130
17	GRAIN HANDLING									
	• Country Elevators	• Fabric Filter	---	---	---	---	---	N/A	~99	
	• Terminal Elevators	• Fabric Filter	---	---	---	---	---	N/A	~99	
18	SECONDARY NONFERROUS METALS									
	• Aluminum Melting									
	• Reverberatory Furnace	• Wet Scrubber	1	---	---	---	82	N/A	~95	10-50
	• Brass and Bronze Melting									
	• Reverberatory	• Fabric Filter	1	---	---	---	140	N/A	~95	9-50
	• Lead Refining									
	• Cupola	• Fabric Filter	2	---	---	---	30	N/A	~95	10-50
	• Zinc Melting									
	• Galvanizing Kettles	• Fabric Filter	1	---	---	---	5	N/A	~95	10-50
	REGIONAL TOTAL	---	---	34	---	5,200	42,028	---	---	---

(1) Natural transition from coal to oil, gas and electric heating, thus no control cost.

(2) Allowable emission rate of 1.46 pounds of sulfur dioxide per million BTU input (control efficiency dependent on sulfur content of existing fuel).

(3) [illegible] emission rate determined by combustion regulation of State of Maryland [illegible] E-2 in Appendix E).

(4) Number of control systems for domestic and commercial incinerators and new municipal incinerators not identified.

(5) Number of power plants is indicated (not the number of boilers).

TABLE 5-10. CONTROL SYSTEM DEMAND FOR THE ST. LOUIS AQCR

SOURCE CODE	SOURCE CATEGORY AND PROCESS	TYPICAL CONTROL SYSTEM TYPE	NUMBER OF SYSTEMS REQUIRED	SUBSTITUTE FUELS REQUIRED: OIL QUANTITY (10^6 gal)	SUBSTITUTE FUELS REQUIRED: OIL SULFUR CONTENT (%)	SUBSTITUTE FUELS REQUIRED: NAT. GAS QUANTITY (10^6 cf)	FULL ADDITIONAL CONTROL INVESTMENT ($1000)	TYPICAL CONTROL EFFICIENCIES (%): SULFUR DIOXIDE	TYPICAL CONTROL EFFICIENCIES (%): PARTICULATE	VOLUME (10^3 acfm)
01	SOLID WASTE DISPOSAL									
	• Municipal Incinerators (Existing)	• Wet Scrubber	2	---	---	---	500	N/A	[illegible]	1-[illegible]
	• Domestic and Commercial Incinerators	• Wet Scrubber	---	---	---	---	1,739	N/A	[illegible]	[illegible]
02	STEAM-ELECTRIC POWER GENERATION									
	• Boiler Flue Gas	• Wet Limestone Scrubbing	5(5)	---	---	---	23,804	(2)	(3)	26-2600
03	INDUSTRIAL BOILERS									
	• Boiler	• Switch to Oil with Sulfur Content less than 1.38%	N/A	337	---	0	0	(2)	[illegible]	1-[illegible]
04	COMMERCIAL-INSTITUTIONAL HEATING PLANTS									
	• Boilers	• Switch to low Sulfur Oil and Natural Gas	N/A	0	---	0	0	(2)	(3)	N/A
05	RESIDENTIAL HEATING PLANTS									
	• Home Heating Units	• Conversion to Distillate Oil and Natural Gas	N/A	26	---	10,410	(1)	(2)	(3)	N/A
06	IRON AND STEEL									
	• Open Hearth	• 40" w.g. Venturi Scrubber	0	---	---	---	12,138	N/A	89.5-97.5	10-650
	• Electric Furnace	• High Temperature Fabric Filter	7	---	---	---		N/A	84-95	30-400
	• Sintering	• 20" w.g. Wet Scrubber	1	---	---	---	1,785	N/A	95-98.8	10-400
07	GREY IRON FOUNDRY									
	• Cupola	• 16-35" w.g. Wet Scrubber	12	---	---	---	698	N/A	85-95	5-150
08	PRIMARY NON-FERROUS METALS									
	• Copper									
	• Smelter	• Acid Plant with Lime Scrubber	0	---	---	---	---	~94	~95	10-500
	• Lead									
	• Refinery	• Acid Plant	0	---	---	---	---	~96	~95	15-300
	• Zinc									
	• Smelter	• Acid Plant	0	---	---	---	---	~93	~95	10-500
09	SULFURIC ACID									
	• Contact Process	• Secondary Absorption Tower	3	---	---	---	2,202	~86	~67	6.5-90
10	PHOSPHATE FERTILIZER									
	• Normal Superphosphate	• Fabric Filter	0	---	---	---	---	N/A	0-80	20-80
11	PETROLEUM REFINING									
	• Refinery	• Sulfur Recovery Plants	4	---	---	---	1,020	~62	~90	100-1500
	• Catalyst Regenerators	• High Efficiency Electrostatic Precipitators	4	---	---	---	650	N/A	~90	20-300
12	ASPHALT BATCHING									
	• Asphalt Batching Process	• 10" w.g. Wet Scrubber	6	---	---	---	84	N/A	79-98.2	10-60
13	CEMENT									
	• Dry Kiln	• Fabric Filter	1	---	---	---	665	N/A	97.8-99.[illegible]	40-300
	• Wet Kiln	• Electrostatic Precipitator	2	---	---	---	2,234	N/A	97.6-99.6	60-650
14	LIME									
	• Vertical Kiln	• Cyclonic Scrubber	0	---	---	---	---	N/A	50-90	5-15
	• Rotary Kiln	• Venturi Scrubber	0	---	---	---	---	N/A	97.[illegible]-99.3	50-125
15	COAL CLEANING									
	• Fluidized-Bed Drier	• 15" w.g. Venturi Scrubber	3	---	---	---	2,055	N/A	~97.8	10-150
	• Flash Drier	• 10" w.g. Venturi Scrubber						N/A	~93.2	10-150
	• Pneumatic Cleaner	• 10" w.g. Venturi Scrubber						N/A	~94.5	
16	GRAIN MILLING									
	• Animal Feed Milling	• Fabric Filter	18	---	---	---	360	N/A	~99	30-130
17	GRAIN HANDLING									
	• Country Elevators	• Fabric Filter	21	---	---	---	537	N/A	~99	
	• Terminal Elevators	• Fabric Filter	21	---	---	---	6,519	N/A	~99	
18	SECONDARY NONFERROUS METALS									
	• Aluminum Melting									
	• Reverberatory Furnace	• Wet Scrubber	6	---	---	---	492	N/A	~95	10-50
	• Brass and Bronze Melting									
	• Reverberatory	• Fabric Filter	4	---	---	---	560	N/A	~95	9-50
	• Lead Refining									
	• Cupola	• Fabric Filter	10	---	---	---	150	N/A	~95	10-50
	• Zinc Melting									
	• Galvanizing Kettles	• Fabric Filter	9	---	---	---	45	N/A	~95	10-50
	REGIONAL TOTAL	---	---	363	---	10,410	67,131	---	---	---

(1) Natural transition from coal to oil, gas and electric heating, thus no control costs.
(2) Allowable emission rate of 1.46 pounds of sulfur dioxide per million BTU input (control efficiency dependent on sulfur content of existing fuel).
(3) Allowable emission rate determined by combustion regulation of State of Maryland (see Figure E-2 in Appendix E).
(4) Number of control systems for domestic and commercial incinerators and new municipal incinerators not identified.
(5) Number of power plants is indicated (not the number of boilers).

TABLE 5-11. CONTROL SYSTEM DEMAND FOR THE PHILADELPHIA AQCR

SOURCE CODE	SOURCE CATEGORY AND PROCESS	TYPICAL CONTROL SYSTEM TYPE	NUMBER OF SYSTEMS REQUIRED	SUBSTITUTE FUELS REQUIRED			FULL ADDITIONAL CONTROL INVESTMENT ($1000)	TYPICAL CONTROL EFFICIENCIES (%)		TOTAL GAS VOLUMES (10^3 acfm)
				OIL		NAT. GAS				
				QUANTITY (10^6 Gal)	SULFUR CONTENT (%)	QUANTITY (10^6 cf)		SULFUR DIOXIDE	PARTIC-ULATES	
01	SOLID WASTE DISPOSAL									
	• Municipal Incinerators (Existing)	• Wet Scrubber	23	---	---	---	3,062	N/A	85-95	10-100
	• Domestic and Commercial Incinerators	• Wet Scrubber	(4)	---	---	---	7,984	N/A	85-95	1-[illegible]
02	STEAM-ELECTRIC POWER GENERATION									
	• Boiler Flue Gas	• Wet Limestone Scrubbing	12$^{(5)}$	---	---	---	53,126	(2)	(3)	29-2600
03	INDUSTRIAL BOILERS									
	• Boiler	• Switch to Oil with Sulfur Content less than 1.38%	N/A	608	---	0	15,609	(2)	(3)	[illegible]
04	COMMERCIAL-INSTITUTIONAL HEATING PLANTS									
	• Boilers	• Switch to low Sulfur Oil and Natural Gas	N/A	7	---	1,960	1,426	(2)	(3)	N/A
05	RESIDENTIAL HEATING PLANTS									
	• Home Heating Units	• Conversion to Distillate Oil and Natural Gas	N/A	43	---	3,950	(1)	(2)	(3)	N/A
06	IRON AND STEEL									
	• Open Hearth	• 40" w.g. Venturi Scrubber	29	---	---	---	35,644	N/A	89.5-97.5	[illegible]-650
	• Electric Furnace	• High Temperature Fabric Filter	21	---	---	---		N/A	84-95	30-400
	• Sintering	• 20" w.g. Wet Scrubber	2	---	---	---	4,083	N/A	95-98.8	10-400
07	GREY IRON FOUNDRY									
	• Cupola	• 16-35" w.g. Wet Scrubber	20	---	---	----	1,348	N/A	85-95	5-150
08	PRIMARY NON-FERROUS METALS									
	• Copper									
	• Smelter	• Acid Plant with Lime Scrubber	0	---	---	---	---	~94	~95	10-500
	• Lead									
	• Refinery	• Acid Plant	0	---	---	---	---	~96	~95	15-300
	• Zinc									
	• Smelter	• Acid Plant	0	---	---	---	---	~93	~95	10-500
09	SULFURIC ACID									
	• Contact Process	• Secondary Absorption Tower	3	---	---	---	1,586	~86	~67	6.5-90
10	PHOSPHATE FERTILIZER									
	• Normal Superphosphate	• Fabric Filter	0	---	---	---	---	N/A	0-80	20-80
11	PETROLEUM REFINING									
	• Refinery	• Sulfur Recovery Plants	4	---	---	---	---	~62	~90	100-1500
	• Catalyst Regenerators	• High Efficiency Electrostatic Precipitators	4	---	---	---	800	N/A	~90	20-300
12	ASPHALT BATCHING									
	• Asphalt Batching Process	• 10" w.g. Wet Scrubber	31	---	---	---	434	N/A	79-98.2	10-60
13	CEMENT									
	• Dry Kiln	• Fabric Filter	0	---	---	---	---	N/A	97.8-99.9	40-300
	• Wet Kiln	• Electrostatic Precipitator	0	---	---	---	---	N/A	97.6-99.6	60-650
14	LIME									
	• Vertical Kiln	• Cyclonic Scrubber	0	---	---	---	0	N/A	50-90	5-15
	• Rotary Kiln	• Venturi Scrubber	3	---	---	---	150	N/A	97.8-99.3	50-125
15	COAL CLEANING									
	• Fluidized-Bed Drier	• 15" w.g. Venturi Scrubber	0	---	---	---	---	N/A	~97.8	10-150
	• Flash Drier	• 10" w.g. Venturi Scrubber	0	---	---	---	---	N/A	~93.2	10-150
	• Pneumatic Cleaner	• 10" w.g. Venturi Scrubber	0	---	---	---	---	N/A	~94.5	
16	GRAIN MILLING									
	• Animal Feed Milling	• Fabric Filter	14	---	---	---	280	N/A	~99	30-130
17	GRAIN HANDLING									
	• Country Elevators	• Fabric Filter	0	---	---	---	---	N/A	~99	
	• Terminal Elevators	• Fabric Filter	2	---	---	---	279	N/A	~99	
18	SECONDARY NONFERROUS METALS									
	• Aluminum Melting									
	• Reverberatory Furnace	• Wet Scrubber	4	---	---	---	328	N/A	~95	10-50
	• Brass and Bronze Melting									
	• Reverberatory	• Fabric Filter	9	---	---	---	1,260	N/A	~95	9-50
	• Lead Refining									
	• Cupola	• Fabric Filter	15	---	---	---	225	N/A	~95	10-50
	• Zinc Melting									
	• Galvanizing Kettles	• Fabric Filter	7	---	---	---	35	N/A	~95	10-50
	REGIONAL TOTAL	---	---	658	---	5,910	127,659	---	---	---

(1) Natural transition from coal to oil, gas and electric heating, thus no control costs.

(2) Allowable emission rate of 1.46 pounds of sulfur dioxide per million BTU input (control efficiency dependent on sulfur content of existing fuel).

(3) Allowable emission rate determined by combustion regulation of State of Maryland (see Figure E-2 in Appendix E).

(4) Number of control systems for domestic and commercial incinerators and new municipal incinerators not identified.

(5) Number of power plants is indicated (not the number of boilers).

The data presented in Tables 5-8 through 5-11 include:

Source Code - a code used in this study for accounting purposes.

Source Category and Process - an identification of the major polluting source types and processes affected by emission regulations.

Typical Control System Type - the control technology most likely to be applied to a majority of the specific processes identified.

Number of Systems Required - the number of control systems required for compliance with the assumed emission standards.

Substitute Fuels Required - an estimate of the type and quantity of fuels which will be substituted for presently used fuels.

Full Additional Control Investment - the estimated cost of the installed control systems for each specific process type in the region.

Typical Control Efficiencies - a range of control efficiencies (in percent) that are required for the specific process type for the two pollutants indicated.

Typical Gas Volumes - the range of gas volume rate typically found for the specific process types indicated.

The following discussion will examine demand estimates in greater detail.

5.2.5.1 Source Category and Process

The major source categories and processes identified are the major contributors of particulate and sulfur dioxide emissions in the model nation. These are sources that will be affected by emission control regulations. The processes identified include those primary processes with any plant, as well as secondary processes. That is to say, more than just the major process within a plant has been included in the analysis. Secondary processes, such as a grey iron cupola in a waffle iron manufacturing plant, have been identified and included in the analysis. Another example of a secondary process is a sulfuric acid plant in a fertilizer complex. Resources such as Dun & Bradstreet, literature from manufacturing associations, Department of Commerce reports, Federal Power Commission surveys, and others, have been used to identify the plants and processes.

5.2.5.2 Typical Control System Type

The "typical control system type" is the specific control technology which has been selected for cost estimating purposes in the ECA Report. The control technology identified is one that will "most likely" be applied to the process. It is, necessarily, a technology which will control the pollutants to a level consistent with the emission standards. In many cases, a process can be controlled with more than one type of control system. In reality, the selection of the control system by a plant is based on the criteria of competitive prices, regional environmental parameters, and other technical conditions.

The main criterion used in selecting the "typical" control system was the capability of attaining the required control efficiency. Technical considerations regarding the gas stream, the pollutant, currently accepted practices in each industry, and the trends in equipment selection were considered in the evaluation process. No supply considerations were examined.

5.2.5.3 Number of Systems Required

The "number of systems required" is an estimate of the number of processes within the model nation which are identified as not in compliance with the emission standards, which have been assumed. It is assumed that all plants will comply with the emission standards by installing externally applied control systems and alternative fuels. No plants will modify processes or shut down the process. Where possible, processes which currently meet assumed emission standards have been identified and have not been included as candidates for control.

5.2.5.4 Substitute Fuels Required

The fuel substitution calculations are heavily dependent on a number of assumptions used in the ECA Report. The major assumptions are:

- The currently available supply of low sulfur fuel is inadequate to fulfill the needs of steam-electric powerplants in the nation. Therefore, wet limestone scrubbing will be used by most plants in this category.

- Other stationary fuel combustion sources now burning coal will switch to either low sulfur oil or natural gas.
- The residential heating market is now undergoing a natural transition from the use of coal to oil, natural gas or electricity.

Because the ECA Report estimating procedure for fuel substitution was dependent on one assumption for any source type, the estimates of expected shifts in fuel demand are of limited value. Certainly, a mix of flue gas desulfurization methods and fuel switching will be used by powerplants.

The estimated quantity of fuels demanded was determined by a BTU balance for the sources identified in the AQCRs. The control investment indicates the conversion costs for switching to low sulfur fuels.

5.2.5.5 Full Additional Control Investment

The "required control efficiency" for processes has been calculated by relating the emission limitation of the assumed emission standards to the emission potential of the processes. A range of control efficiencies is presented since many or most of the emission standards base the allowable quantity of emissions on process size. The "required control efficiency" estimates have been determined for a range of process sizes which are typically operated in the nation. The efficiencies reported are not merely representative of the process sizes found in the four selected AQCRs.

5.2.5.6 Typical Gas Volumes

A range of gas volumes is presented as an indicator of control system size required for any given process. The range is an estimate of the gas volumes found on the nation's most typical processes. The control volumes reported are not merely representative of sources in the four AQCRs.

5.3.0 Limitations of the 305(a) Approach

The 305(a) Approach and example control measure demand estimates have been presented. Estimates have been determined for a selected group of major polluting industries. The control systems demanded are the resources needed to limit air pollutant emissions from processes not now in compliance with newly proposed emission standards stimulated by the Clean Air Act.

An evaluation of the limitations of the 305(a) Approach is needed. This evaluation focuses on the expected accuracy of the demand estimates. Other aspects of the Approach have been previously evaluated, such as the availability of data and the simplicity of the calculations.

Because the quality of the demand estimates from the 305(a) Approach are directly dependent upon the ECA Report control cost estimates, the ECA Report cost estimating procedures are, in essence, being examined. Theoretically, the examination should be a comparison between the actual control systems and costs that are demanded (i.e., a "perfect" assessment) and control systems and costs estimated by the ECA Report. A "perfect" demand study requires a source-by-source engineering evaluation of current emissions and the least-cost control system to meet the desirable air quality. Such a study requires the following tasks:

(i) The identification of all sources of pollution that need control

(ii) The development of information on the process type, size, and other plant characteristics

(iii) The documentation of the current level of emissions control

(iv) An analysis of the specific control technology that will reduce emissions at least cost to the level required by the appropriate emission standard

(v) The determination of a detailed estimate of the installation and annual cost of operating the system.

Yet, such a "perfect" study is not in the interest of society because of the excessive time and the resources needed to obtain such detailed decision-making information. The procedure developed for the ECA Report approximately predicts the costs of control and accomplishes this task with limited resources.

This Section identifies the gaps between the "perfect" demand estimates that might result from a detailed engineering evaluation of each and every source and the results obtained from the ECA Report control cost estimating-procedures and the 305(a) Approach. Conclusions on the merits of the 305(a) Approach are not made until the comparison of the three approaches have been conducted in the summary in Section 1.0.

As previously identified, the ECA Report control cost estimating procedure is comprised of five methods. A comprehensive evaluation of each of the methods is desirable but beyond the scope of this report. Such an effort should evaluate the strengths and weaknesses of each method relative to specific criteria. The evaluations should shed light on the expected accuracy of the ECA Report estimates and identify the areas of the ECA Report cost estimating procedure that could be most profitably strengthened (i.e., areas where additional efforts will bring the greatest improvement in the desired results).

Although such an evaluation is not possible here, some limitations have been identified and are presented in order that the three proposed approaches for estimating control measure demand can be reasonably compared in Section 1.0.

The four criteria used in the evaluation are:

(i) Comprehensiveness of source identification
(ii) Completeness of the source characteristics
(iii) Appropriateness of the selected control system
(iv) Accuracy of control cost estimates

It is important to understand how these criteria are used. First, the ECA Report cost estimating procedures are investigated to see if all affected sources have been identified. Second, it is assumed that all sources have been identified and only the characteristics of the identified source, such as size and current level of control, are to be evaluated. Third, it is assumed that sources have been precisely characterized and the selection of the most appropriate control systems are to be investigated. Finally, sources with the most appropriate control system are assumed and the accuracy of the control cost estimates are questioned. The evaluation is conducted in the following manner: first, the evaluation criteria are stated; second, important questions regarding the criteria are cited; and, third, specific merits or deficiencies of the ECA Report data and procedures are stated and alternatives expressed.

5.3.1 Comprehensiveness of Source Identification

The question under consideration is whether or not all sources affected by the control regulations have been identified. All sources in the source categories analyzed by Methods I and II have been accurately located (including the identification of individual processes). Specific plants have also been identified for some industries analyzed by Methods III A and III B.

Individual sources in the grain handling industry (Method III B) have not been identified. Also, other fuel combustion sources (commerical, institutional and residential), small incinerators, and industrial boilers have not been individually identified (Method IV).

5.3.2 Completeness of the Identification of Source Characteristics

The questions under consideration are: Have the size (and other relevant characteristics) of each source been identified? and, Is the current level of emissions control known?

(i) The size of processes and plants are known where methods I and II are used in estimating control costs.

(ii) The size of sources is not known in cases where Methods III A and B and IV are used. This means that data on the distribution of control measure size is not available for these source categories. Also, lack of information on fuel combustion source size prevents detailed estimates of alternative control practices which may be applied (for example, it is likely that large fuel combustion sources may use wet scrubbing devices, whereas, small fuel combustion sources may be controlled by fuel switching).

(iii) Information on the current level of control is inadequate for nearly all source categories (the primary copper smelting industry may be an exception). This factor prevents the analyst from distinguishing between sources which merely require an upgrading of the control system and those which require totally new systems. Also, specific sources which are currently using low sulfur fuel (or fuel with a low ash content) are not always clearly identified.

This information is very important for predicting control system demand and costs for the control of powerplants as well as other stationary fuel combustion sources.

5.3.3 Appropriateness of the Selected Control System

The questions under consideration are: Are the assumed emission standards (which stipulate the required emission control efficiency) appropriate for the air quality standards of the political jurisdiction where sources are located? Have the control systems with the greatest likelihood of application been identified for each source? Are all of the demanded fuels and control systems technologically feasible?

(i) The ECA Report procedure applies uniform emission standards to all sources. The standards are relatively stringent, that is, adequate to meet air quality standards in the nation's major metropolitan areas (see Section 1.0 in this study). A more accurate technique would vary the emission standards in each AQCR according to the existing air quality levels. Such an approach may be practical after the submittal of implementation plans.

(ii) The ECA Report assumes the application of one control technology for all processes of a similar type. Although this procedure is entirely adequate for cost estimating purposes, it is inadequate for a demand study. Currently, alternative (i.e., competitive) control techniques exist for most processes. Certain system designs are more cost-effective at some locations or for some size processes than others. Factors, such as the availability of water, access to markets, or, climate, influence the selection of the control system. Because the control measure demand estimate for a process is limited to only one control technology, the alternative control systems and the expected frequency of utilization is not predicted (for example, it is not possible to predict the proportion of gray iron foundries that will use wet scrubbers, fabric filters, electrostatic precipitators or switch to electric induction melting).

(iii) The supply of economically reasonable and technically feasible control technologies has a direct effect on control measure demand estimates. Today, there are many questions regarding the availability of control systems, especially for the control of gaseous pollutants. The 305(a) Approach estimates the demand for the "most-likely" candidate control system. In cases where no economically reasonable control technologies have been demonstrated (and where promising alternatives are now under evaluation), the alternatives and, if possible, the expected probability of success of such alternatives, should be cited.

5.3.4 Accuracy of Control Cost Estimates

The questions under consideration are: How accurate are the control cost estimates for fuel substitution and control hardware? Have all the relevant costs been included in the control cost estimates?

(i) Projected supply and demand relationships have not been factored into the control cost calculations for low sulfur fuel substitutions. Economic studies of the necessary relationships are needed to truly reflect the substitution costs (as current fuel prices wildly fluctuate).

(ii) Some costs, such as the cost for shipping control systems (i.e., transportation costs), have been deleted from the control cost estimates. A demand study should reflect these costs.

(iii) The control costs for some industrial categories are based on linear and non-linear control cost functions developed for the control technique documents. Specific engineering studies of such source categories will improve the quality of the control cost estimates.

In summary, the ECA Report data bank is a useful source of information for control measure demand estimates. Limitations in the data have been identified. In general, the estimates for industrial process sources where Methods I and II are used are more accurate (and informative) than those estimates determined by Methods III A and B. The fuel use and flue gas desulfurization demand estimates are the least useful because of:

(i) Lack of detailed information;

(ii) The current uncertainties in the supply-demand relationships for low sulfur fuels; and,

(iii) The potential impact of flue gas desulfurization techniques.

Demand studies using the 305(a) Approach can be significantly improved if current source data (1971) is used. Naturally, forecasts of sources and emissions are even more desirable. Demand studies should also be longitudinal, that is, the study should predict demand as a function of time. Control system demand should be related to the expected rate of enforcement of emission control regulations.

To conclude, a study which merges an up-graded version of the current data bank with accurate predictions of new control technology developments, the growth of industrial activities, and the rate of air pollution control enforcement will determine the desirable decision-making information.

6.0 REFERENCES

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APPENDIX A

IMPLEMENTATION PLANNING PROGRAM

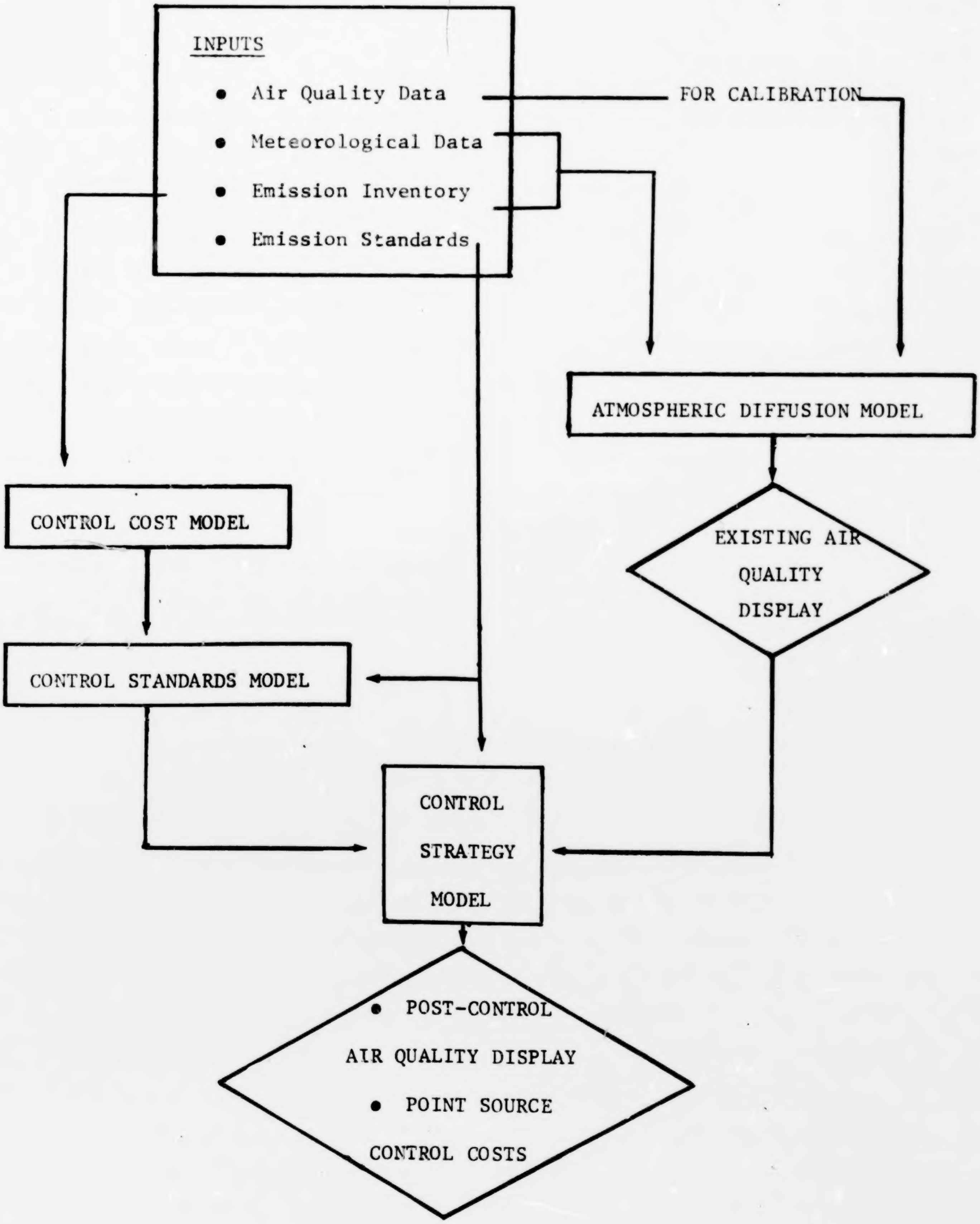
The Implementation Planning Program (IPP) is a series of models developed by TRW under contract to APCO which help in the evaluation of alternative strategies for control of air pollution sources. A flow chart of the program is illustrated in Figure A-1.

The heart of IPP is the atmospheric diffusion model, which predicts expected regional ambient concentrations of pollutants by mathematically simulating the dispersion of these pollutants throughout the region. The inputs to this model are a detailed emission inventory, various meteorological data, and measured pollutant concentration data. The emission inventory lists individually the major sources of pollutants (powerplants, incinerators, etc.) and describes in detail those parameters which characterize the sources and their emissions. The inventory also characterizes those emission sources which are too small to be identified individually by aggregating them to form "area sources." The meteorological data includes wind speed and direction, mixing depth, and other phenomena which describe the transport mechanism which carries the pollutants from the sources throughout the region. The measured concentration data is used to calibrate the theoretical model, in order to account for inaccuracies in the diffusion equation, inaccurate source emissions and meteorological data, irregularities in the area's topography (the diffusion equation assumes a flat plain), and other errors.

Besides predicting present air quality conditions, IPP can predict the effects of a pollutant control "strategy" (a series of emission control standards which apply to all major sources in the area) on the area's air quality and measure the resulting pollution control device demand and cost. This is accomplished by a control cost, a control standards, and a control strategy model.

The control cost model assigns to each major source all those control devices which may reasonably be used for reducing emissions. Devices for the control of particulates are generally applied to the outlets of the polluting process (usually the stacks). Sulfur dioxide control is usually

Figure A-1. Flow Chart


INPUTS
• Air Quality Data
• Meteorological Data
• Emission Inventory
• Emission Standards
FOR CALIBRATION
ATMOSPHERIC DIFFUSION MODEL
EXISTING AIR QUALITY DISPLAY
CONTROL COST MODEL
CONTROL STANDARDS MODEL
CONTROL STRATEGY MODEL
• POST-CONTROL AIR QUALITY DISPLAY
• POINT SOURCE CONTROL COSTS

accomplished by switching to low sulfur fuels or by the use of flue gas desulfurization techniques. The model's output consists of lists of device names, their efficiencies and costs, and their effects on pollutant emissions, for each major emission source.

The control standards model applies a series of emission standards to the three categories of emission sources: fuel combustion, industrial process, and solid waste disposal sources. Output consists of a list, for each major source, of the applicable standards, their prescribed allowable emissions, suitable control devices selected on the basis of effectiveness and least cost (one device for each standard), and the cost and effect on emission of the devices (obtained from the control cost model).

The control strategy model calculates the effects of applying selected sets of three emission standards (two in the case of SO_2) to every political jurisdiction in the control area. Selecting the applicable results from the control standards model, the model develops a picture of the change in emissions (and costs) resulting from a realizable pollution control alternative. Using the output of the atmospheric diffusion model, the strategy model recomputes the pollutant concentration distribution resulting from the new emission pattern, thus allowing a decision to be made on the effectiveness of the strategy based on both the resulting costs (on a regional, industry-by-industry, political jurisdiction-by-political jurisdiction, or source-by-source basis) and the actual air quality produced by implementation of the standards.

APPENDIX B

ESTIMATING CONTROL COSTS

The industry-wide and regional costs of air pollution control presented in this report are obtained by a detailed source-by-source cost analysis conducted with the Implementation Planning Program described in Appendix A. These costs represent the cost to a major industry group or region of buying, installing, and operating selected control devices in order to control emissions to the degree required by an air pollution standard. It should be noted that pollution sources which are smaller than some predetermined size are aggregated and included in the analysis as area sources (the large individual sources are called point sources). These area sources play a role in the air quality predictions output by the model but are not included in the cost calculations (regional control agency costs are also excluded). Typically, the components of area sources are automobiles, apartment house incinerators, small industries and boilers, etc.

The basis used in this report for estimating the cost of control of an individual point source is as follows:

A. The source is defined in some detail. Process details, fuel consumption, stack exit conditions and size, plant capacity, and other variables are specified.

B. Those control devices which can be applied to this class of source are selected; the total annual cost of control and the device efficiency are calculated for each selection. Costs are based on source parameters, known device parameters, and certain regional information such as labor costs, interest rates, etc.

C. An emission standard is specified; from this, a required collection efficiency is calculated.

D. The lowest-priced device of those that can equal or exceed the desired efficiency is selected, with the

> proviso that if none are sufficient, the most effective device will be chosen regardless of cost. This method of selecting control devices, based on individual source characteristics, contrasts with that employed in the Cost of Clean Air report. The methodology used there involves the application of a single device type to all the plants in a specified industry group. Device selection is based on analysis of a typical or model plant. The flexibility of the IPP approach is illustrated with an example from the Cincinnati 305(a) strategy. Application of the San Francisco Process Weight regulation for industrial process sources to asphalt batching plants in the Kentucky jurisdiction dictates the selection of three device types for the four applicable sources--a medium temperature fabric filter with a 99 percent control efficiency, a medium efficiency cyclone with a 75 percent efficiency, and two high efficiency cyclones with 85 percent efficiencies.

Step B in the selection process deserves considerably more explanation. The applicability of a control device to a particular source depends upon a large number of engineering factors related to both source and device characteristics. For instance, some devices cannot handle the high temperature corrosive gas streams associated with certain source types. Other devices are designed for control of gaseous pollutants only, or particulates only; a fabric filter is obviously unsuitable for control of an SO_2 source. The program handles the selection problem by identifying sources using the four digit Standard Industrial Classification (SIC) and specifying for each classification a list of applicable devices. A fifth digit is added to the classification when more detail is necessary (for instance, distinguishing between an electric arc and open hearth furnace).

Table B-1 presents the range of applicability of the control devices considered by the model for each source type. Note that all combustion sources are subject to devices specified in the first row.

TABLE B-1. APPLICABLE CONTROL DEVICES

SOURCE TYPE		CONTROL DEVICE TYPE																																			
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	27	28	29	30	31	32	33	39	40	41	42	43	44	45
COMBUSTION								O	O	O	O	O	O				O	O	O					O	O	O	O	O	O	O	O	O	O	O			
SIC 2040	Feed and Grain							O	O	O							O	O	O																		
SIC 2819 nnn1	Sulfuric Acid													O	O	O																					
SIC 2819 nnn2	Nitric Acid	O	O	O											O																						
SIC 2819 nnn3	Ammonium Nitrate	O	O	O																																	
SIC 2822	Synthetic Rubber																O	O	O																		
SIC 2851	Paint and Varnish		O	O																O	O	O	O														
SIC 2871	Fertilizers										O	O	O				O	O	O																		
SIC 3210	Flat Glass	O	O	O													O	O	O																		
SIC 3241	Cement Manufacturing							O	O	O	O	O	O				O	O	O																		
SIC 2951	Asphalt Batching	O	O	O				O	O	O							O	O	O																		
SIC 3250	Structural Clay Prod.	O	O	O				O	O	O							O	O	O																		
SIC 3295	Rock, Sand & Gravel	O	O	O				O	O	O							O	O	O																		
SIC 3312 nnn1	Iron & Steel/Blast Furn	O									O	O																									
SIC 3312 nnn2	Basic Oxygen Furnace	O									O	O																									
SIC 3312 nnn3	Sintering							O	O	O	O	O	O																								
SIC 3312 nnn4	Coking Operations																																				
SIC 3312 nnn5	Electric Arc Furnace	O									O	O					O	O	O																		
SIC 3312 nnn61	Open Hearth Furnace	O									O	O					O	O	O																		
SIC 3323	Steel Foundries	O	O	O				O	O	O							O	O	O																		
SIC 3332 nnn1	Lead Smelters/Sintering										O	O	O	O																					O	O	O
SIC 3332 nnn2	Blast Furnace										O	O	O																								
SIC 3332 nnn3	Reverbatory Furnace										O	O	O	O																					O	O	O
SIC 4953	Solid Waste Disposal	O	O	O				O	O	O																											
SIC 2911	Petroleum Refinery							O	O		O	O																									
SIC 2800	Chemical & Allied Prod.													O																							

Table B-1. APPLICABLE CONTROL DEVICES (Continued)

POLLUTION REDUCTION DEVICES OR METHODS

001	Wet Scrubber - High Efficiency
002	Wet Scrubber - Medium Efficiency
003	Wet Scrubber - Low Efficiency
004	Gravity Collector - High Efficiency
005	Gravity Collector - Medium Efficiency
006	Gravity Collector - Low Efficiency
007	Centrifugal Collector - High Efficiency
008	Centrifugal Collector - Medium Efficiency
009	Centrifugal Collector - Low Efficiency
010	Electrostatic Precipitator - High Efficiency
011	Electrostatic Precipitator - Medium Eff.
012	Electrostatic Precipitator - Low Efficiency
013	Gas Scrubber
014	Mist Eliminator - High Velocity
015	Mist Eliminator - Low Velocity
016	Fabric Filter - High Temperature
017	Fabric Filter - Medium Temperature
018	Fabric Filter - Low Temperature
019	Catalytic Afterburner
020	Catalytic Afterburner with Heat Exchanger
021	Direct Flame Afterburner
022	Direct Flame Afterburner with Heat Exchanger
027	Fuel Substitution to Low Coal A
028	Fuel Substitution to Low Coal B
029	Fuel Substitution to Low Coal C
030	Fuel Substitution to Low Sulfur Oil A
031	Fuel Substitution to Low Sulfur Oil B
032	Fuel Substitution to Low Sulfur Oil C
033	Fuel Substitution to Natural Gas
039	Catalytic Oxidation - Flue Gas Desulfurization
040	Alkalized Alumina
041	Dry Limestone Injection
042	Wet Limestone Injection
043	Sulfuric Acid Plant - Contact Process
044	Sulfuric Acid Plant - Double Contact Process
045	Sulfur Plant

The philosophy of calculating the actual cost of control given the source and device type closely follows that expressed in the APCO "Control Techniques for Particulate Air Pollutants" document. Total cost is based on:

- manufacturer's price
- installation costs
- annual capital charges
- operation and maintenance costs.

These factors are in turn based on device characteristics, detailed source characteristics (such as gas stream velocity and temperature, stack sizes, fuel use, plant capacity, etc.), desired efficiency, and locational factors (utilities prices, labor charges, etc.). The model considered "point" devices, i.e., devices with a specified design and efficiency. When a range of efficiency or other design characteristics are necessary in order to truly represent a class of devices, a "high, medium, and low" design are utilized. Costs for the specified device are then dependent solely on source and locational characteristics. Although a collection efficiency is specified for each device, it is recognized that there are different degrees of efficiency associated with the use of a device on different kinds of sources, and efficiency correction factors have been installed in the model for each source type/device type combination.

Manufacturer's Price

The general form of the equation used to calculate manufacturer's price is

$$y = a + bx + cx^2$$

where

y = cost in thousands of dollars

x = some measure of source size (Examples: exhaust gas volume, steam electric power plant, generating capacity in Mw, amount of sulfur emitted in tons/day, etc.)

a,b,c = coefficients dependent upon device characteristics.

Accuracy of the equations is enhanced by specifying different coefficients according to varying ranges of a source variable. For instance, as the percentage P of SO_2 in the exhaust volume of a lead smelting plant varies, the coefficient "a" of the cost equation for device 43 is allowed to vary as follows:

$0 \le P \le 3.0$	a = -0.8218
$3.0 < P \le 6.0$	a = 1.0647
$6.0 < P \le 10.0$	a = 1.2937
$P > 10.0$	a = 1.3449

Installation Cost

The cost of installing a control device on a particulate source is calculated by applying a factor expressed as a percentage of the manufacturer's price. For devices which require extensive modification of the source, installation cost is included in the manufacturer's price calculation.

Annual Capital Charge

The capital charge is based on the rated life of the control device and the prevailing (regional) interest rates.

Operating and Maintenance Costs

A number of factors must be considered in determining the operating and maintenance cost of a particular source-device combination: The amount of power (calculated as electrical power) necessary to force the effluent gas stream through the control device, the quantity of labor required and its cost per hour, the cost of liquid or additional fuel used by the device, the cost or credit resulting from disposal of the collected pollutant, the replacement cost of certain device components (such as filters), and others. For most devices, an equation of the form

$$O \& M = \Sigma \text{ (factor unit cost) * (factor rate)}$$

(Example: factor = electricity, kwhr/yr; rate = \$/kwhr) can be used. Other sources utilize equations based on manufacturer's specifications and operating experience reported in the literature, and are of slightly different form.

Fuel Substitution

One "device" which is not included in the above discussion is fuel substitution. Briefly, substitution costs are calculated by assuming that the old fuel is replaced by a quantity of fuel which will yield an equivalent heat energy output, taking into account the efficiency of the boiler (which varies with fuel type) and the BTU content of both old and new fuel. "Cost" of this control method is simply the difference between the cost of the new fuel and that of the old.

Sources of Error

It should be recognized that details which are ignored in the calculations can be quite important in the total cost for a single source and can cause the calculation for that source to be substantially in error. A partial list of possible sources of error is as follows:

- Gas corrosive level or temperature which is well above average for a particular source category.
- Inaccessibility of site causing transportation costs to be above average.
- Special structural problems in the plant requiring expensive construction techniques, structural modifications, etc.
- Sudden high demand for device or fuel substitute following passage of regulation causing prices to rise and/or shortages to develop.
- Zoning and other regulations requiring special noise abatement procedures.
- Possible differences in company maintenance procedures.
- Possible need to expand electrical and waste treatment facilities, water supply, etc., to accommodate device.
- Scheduling problems requiring extensive overtime and/or specialized labor.
- Differences in device base prices due to degree of instrumentation, quality of workmanship and materials, competitive market or lack of it, etc., etc.

Despite these and other factors, the cost estimates for an entire industry group, averaged over several sources, should be reasonable and quite adequate to serve as a basis for decision-making with regard to selecting control measures and regulations and for estimating total control costs for a region. However, great care should be taken in interpreting the IPP results for specific sources.

APPENDIX C

AREA SOURCE SCALE FACTORS

The IPP model does not apply emission standards to area sources. However, it is possible to manually input scale factors which will alter the emission from these sources, thus simulating the effect on air quality of applying new standards.

The effort involved in individually scaling every area source in a region is very great. A more tractable approach is to assume that the distribution of the various area source components--transportation, residential space heating, etc.--is fairly uniform; two scale factors (one for each pollutant), applied to all area sources, will then suffice.

Using the Cincinnati AQCR as an illustration, area source scale factors may be derived as follows.

Using data supplied by APCO's Division of Abatement, the composition of the Cincinnati AQCR area sources can be defined in Table C-1. According to the data, the area sources contain no industrial process emissions.

The emission standards to be applied to these sources can be obtained by inspection from Appendix D. Note that all component sources of an area source are, by definition, SMALL SOURCES; therefore, the lower-end of the appropriate regulations apply. Table C-2 lists the standards for area sources.

In order to scale down the emissions in Table C-1, one must first calculate the emissions of the sources, on a unit basis, under present conditions (or, under the conditions when the data in Table C-1 was valid). This can turn out to be a difficult task, because control of those emission sources which are included in an "area source" has not been very well defined. For the most part, analysts have tended to compute emissions from area sources by assuming that they are uncontrolled. This is probably the most reasonable approach, and will be followed here. Emission factors were obtained from Reference 3.

TABLE C-1. COMPOSITION OF CINCINNATI AREA SOURCES

Component	Percent of Total Emissions	
	Particulates	SO_2
• Fuel Combustion Sources	42.6	83.5
• Bituminous Coal	37.1	74.7
• Resid	.5	3.8
• Distillate	1.3	5.0
• Gas	3.7	0
• Fuel Combustion Mobile Sources	22.8	14.3
• Refuse Disposal Sources	34.6	2.3
• Open Burning	23.4	2.2
• Other	11.2	.1
	100%	100%

TABLE C-2 305(a) STANDARDS FOR AREA SOURCES

PARTICULATE ALLOWABLE EMISSIONS

- Fuel Combustion - .6 pounds/10^6 BTU
- Industrial Process - 11 pounds/ton input
- Solid Waste Disposal - 6 pounds/ton refuse charged

SO_2 ALLOWABLE EMISSIONS

- Fuel Combustion - 1.46 pounds/10^6 BTU
  or 1 percent sulfur coal
  or 1.38 percent sulfur oil
- Industrial Process 500 parts/million

In order to scale down the emissions in Table 3-3, one must first calculate the emissions of the sources, on a unit basis, under present conditions (or, under the conditions when the data in Table 3-3 was valid). This can turn out to be a difficult task, because control of those emission sources which are included in an "area source" has not been very well defined. For the most part, analysts have tended to compute emissions from area sources by assuming that they are uncontrolled. This is probably the most reasonable approach, and will be followed here. Emission factors were obtained from Reference 3.

- Particulates

    - Bituminous Coal

        Uncontrolled emission, pounds per ton $\cong$ 5A

        where A = ash content by weight

        $\cong$ 8 percent in Cincinnati

        Uncontrolled emissions = 40 pounds per ton

        Allowable emissions = .6 pounds/10^6 BTU

        $\cong$ 15 pounds per ton

        (Heat content of coal is about 25 x 10^6 BTU per ton)

        SCALE FACTOR = 15/40 = .375

    - Residual Fuel Oil, Distillate and Natural Gas

        All three fuels produce very low particulate emissions and satisfy the fuel combustion standard.

        SCALE FACTOR = 1.00

    - Fuel Combustion, Mobile

        This source is unaffected by the 305(a) standards.

        SCALE FACTOR = 1.00

    - Open Burning

        The 305(a) report calls for elimination of open burning, substitution of land fill.

        SCALE FACTOR = 0

- Other Refuse Disposal

  Uncontrolled emissions ≅ 17 pounds per ton charged
  Allowable emissions = 6 pounds per ton charged
  SCALE FACTOR = 6/17 = .35

- SO_2

  - Bituminous Coal

    Average sulfur level is 1 percent in Cincinnati, satisfies standard.

    SCALE FACTOR = 1.00

  - Residual and Distillate

    Average sulfur level in Cincinnati is, respectively, 1.36 percent and less than 1 percent, both of which satisfy the standard.

    SCALE FACTOR = 1.00

  - Gas

    Natural gas emits essentially zero SO_2.

    SCALE FACTOR = 1.00

  - Fuel Combustion, Mobile

    Unaffected by 305(a) standards

    SCALE FACTOR = 1.00

  - Open Burning

    Elimination of open burning.

    SCALE FACTOR = 0

  - Other Refuse Disposal

    Unaffected by 305(a) standards.

    SCALE FACTOR = 1.00

The overall scale factor for each pollutant is simply:

$$SF = \sum_i \text{(Fraction of total emission, component i)} \times \text{(Appropriate scale factor for i)}$$

SCALE FACTOR, PARTICULATES = .463
SCALE FACTOR, SO_2 = .978

Table C-3 lists the scaling factors for all the detailed inventory strategies investigated in this report.

TABLE C-3 AREA SOURCE SCALING FACTORS

AQCR	SO_2		PARTICULATES	
	Strategy	Scale Factor	Strategy	Scale Factor
Cincinnati	305(a)	.978	305(a)	.463
St. Louis*	305(a)	.477	305(a)	.463
			1/4 305(a)	.338
Washington, D.C.	305(a)	1.00	305(a)	.73
	1/2 305(a)**	.7795	1/2 305(a)	.6323

* Data on breakdown of area sources was not available; Cincinnati breakdown was used instead.

** 1/2 305(a) ≡ twice as stringent as 305(a)

APPENDIX D

EMISSION STANDARDS

The emission standards used as a base in this report are those utilized in the 1970 "Cost of Clean Air" and the 1971 "Economics of Clean Air" reports submitted to Congress in compliance with Section 305(a) of the Clean Air Act, as amended. There are five regulations for the control of particulates and sulfur oxides:

Particulates

1. Fuel combustion sources--Maryland Particulate Emission Standard for Fuel Burning Installations, allowable emissions versus equipment capacity rating (Figure D-1).
2. Industrial process sources--San Francisco Bay Area Pollution Control District Process Weight Regulation, allowable emissions versus process weight (Table D-1).
3. Solid Waste Disposal--New York State Particulate Emission Standard for Refuse Burning Equipment, allowable emissions versus refuse charged (Figure D-2); banning of open burning.

SO_2

4. Fuel Combustion Sources--allowable emission rate of 1.46 pounds of sulfur dioxide per million BTU input (equivalent to one percent restriction on sulfur content, by weight, in coal, and a 1.38 percent restriction in oil).
5. Industrial Process Sources--allowable emission of 500 parts per million of sulfur dioxide.

TABLE D-1. Allowable Rate of Particulate Emission Based on Process Weight Rate

Process weight rate		Rate of emission, lbs/hr	Process weight rate		Rate of emission, lbs/hr
Lbs/hr	Tons/hr		Lbs/hr	Tons/hr	
100	0.05	0.551	16,000	8	16.5
200	0.10	.877	18,000	9	17.9
400	0.20	1.40	20,000	10	19.2
600	0.30	1.83	30,000	15	25.2
800	0.40	2.22	40,000	20	30.5
1,000	0.50	2.58	50,000	25	35.4
1,500	0.75	3.38	60,000	30	40.0
2,000	1.00	4.10	70,000	35	41.3
2,500	1.25	4.76	80,000	40	42.5
3,000	1.50	5.38	90,000	45	43.6
3,500	1.75	5.96	100,000	50	44.6
4,000	2.00	6.52	120,000	60	46.3
5,000	2.50	7.58	140,000	70	47.8
6,000	3.00	8.56	160,000	80	49.0
7,000	3.50	9.49	200,000	100	51.2
8,000	4.00	10.4	1,000,000	500	69.0
9,000	4.50	11.2	2,000,000	1,000	77.6
10,000	5.00	12.0	6,000,000	3,000	92.7
12,000	6.00	13.6			

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[1] Data in this table can be interpolated for process weight rates up to 60,000 lb/hr by using equation: $E = 4.10 P^{0.67}$; and can be interpolated and extrapolated for process weight rates in excess of 60,000 lb/hr by using equation: $E = 55.0 P^{0.11} - 40$ (E = rate of emission in lb/hr; P = process weight rate in tons/hr).

Figure D-1. Maryland Particulate Emission Standards For Fuel Burning Installations

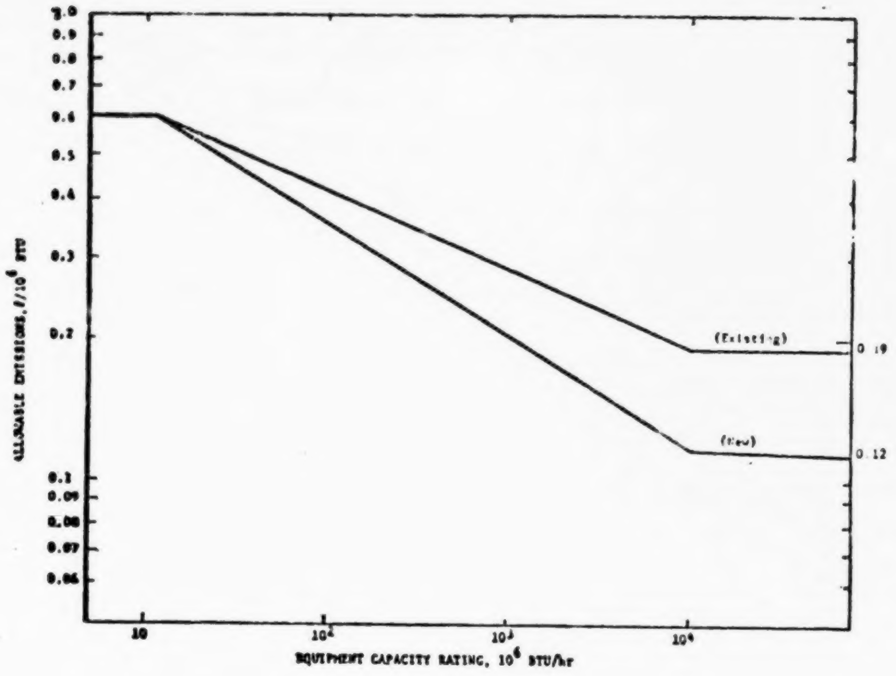

Figure D-2. New York State Particulate Emission Regulation For Refuse Burning Equipment